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Ministry of Education
General Directorate of Curricula

CHEMISTRY

2

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PREFACE

Chemistry: basic science - today - in the leadership rode accelerated progress globally positive interaction and mutual benefit with the rest of the natural sciences of physics and geologist and diverse life science branches. This book represents a gesture that emerged from the seed valid, to see the light and grow with the help of God. Guided all constructive honest opinion and criticism purposefully Secretary of all irrelevant from various segments of society, teachers, parents and professionals and educational and social organizations and other wide upgrading and refinement are ongoing processes sustain life. The book Chemistry for Grade average; complement the content of its chapters to its predecessor book (Principles of Chemistry) first stage intermediate stage (previous year-old students') first edition and take it out scientific and technical advanced; first brick in the edifice of chemistry, for our yearning to live in safety and peace, keep pace in the developed world continue to improve living conditions in all aspects of life, that's just a simple comparison between the two books suggest.

Here we would like to emphasize the need and importance of the practical side for two main reasons firstly that practical experience, theoretical accompanying article deepens accommodate students for content vocabulary. And motivate them to continue to increase science brief time and effort...The second send the petition practical experiences of suspense and attract the attention of multiplier by the students to follow the scientific results that brings tranquillity and comfort in them eager to learn everything new. And it can be implemented as overwhelmed book targets cognitive, behavioral and skill; without giving practical side (planned in advance by the teacher) something worth of importance depending on what civilized by the local environment of alternatives to the shortcomings of what is available in the laboratory of the school and the nearby schools of chemicals and tools and number along with other teaching aids available, such as charts and drawings, types fixed and mobile computers.

The use of laboratory and teaching aids available widely used scientifically engineered; would speed up the theoretical side and down to complete the prescribed curriculum satisfactorily. And within the period prescribed for that and not the other way around never practical tests - no matter how simple - just boredom for students and provide valuable time for the teacher. We also organize trips quality (scientific entertainment at the same time) for laboratories and factories nearby to inform students on the ground on the steps transform raw materials (ores) to materials semi-manufactured and manufactured benefit society and commissioning students (in the form of groups) to prepare simple reports the results of the visit with open free debate between students and professionals in the field productive as far as time permits.

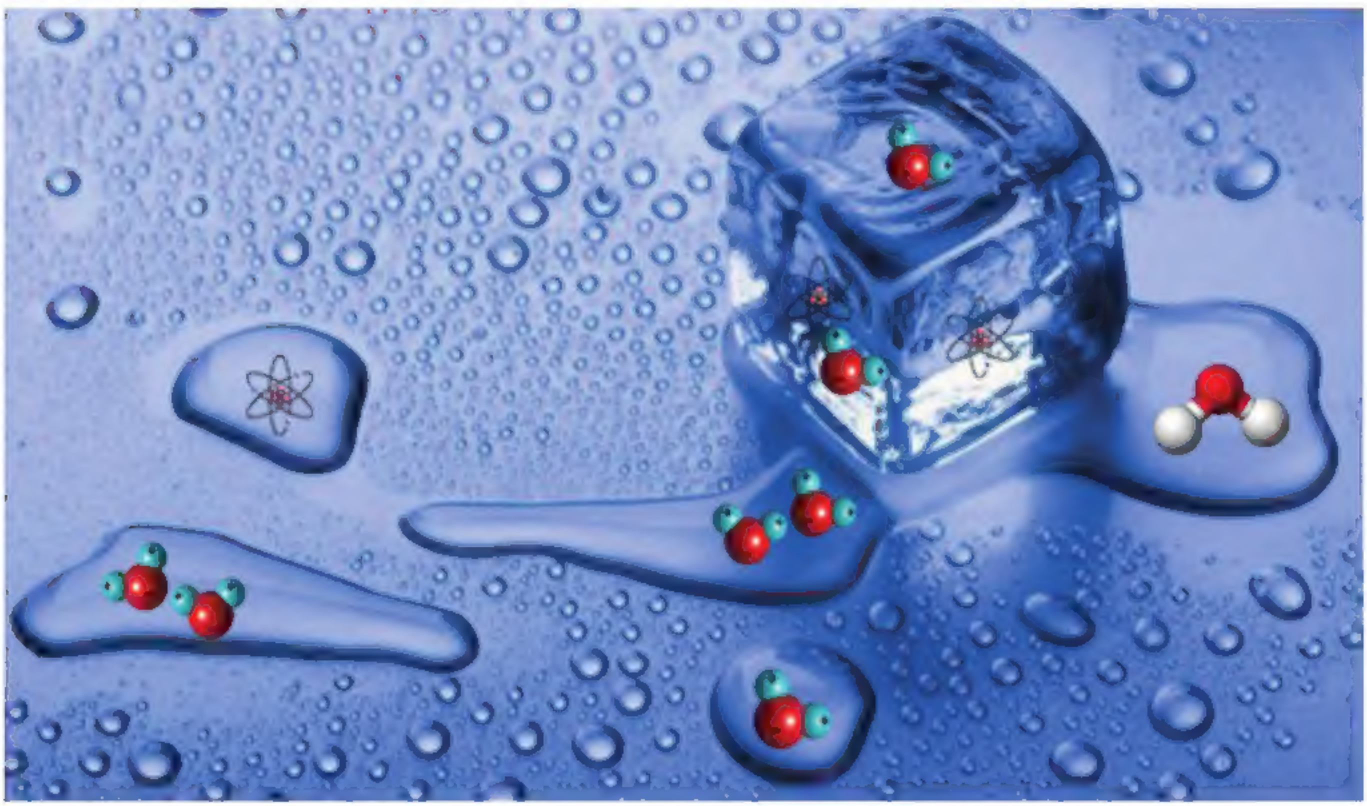
Finally we hope teachers and specialists brothers and all of the relevant submit to the Directorate General of curriculum / textbooks and curricula Directorate everything possible to develop and modernize the rule book service of the educational process in our dear country.
It is reconciled to God

The Author

CONTENTS

CHAPTER 01

BUILDING BLOCKS OF MATTER



ACHIEVEMENTS

After complete studying this chapter, the student should be able to:

* gives a definition for atom and molecule and enumerates the basic components of atom.
* gives a definition for the nucleus of an atom and a proton, neutron and electron and atomic number and mass number.
* expresses the relationship between the atomic number and mass number and number of neutrons.
* enumerates electronic volumes around the nucleus and its figures and symbols and draw electronic arrangement of atoms.
* recognize the ionization process and distinguishes between the positive and negative ions.
* recognize the attractive forces between the constituent atoms of molecules.
* knows the meaning of chemical bonding and their types and number of parity and the oxidation number.
* Know how to write chemical formulas for compounds and understand the periodic table of the elements and how to arrange the items in it.

Chapter - 1

1-1 INTRODUCTION

The air, water and clouds, mountains, plants and animals and the human body and the chair you sit on the book which is in your hands and everything you see and touch and feel it is matter. "Matter is everything occupies space and has mass." The Greek philosophers of the early contributors to put a picture for construction of matter and then came Arabic scientists like Jabir Ibn Hayyan who have stated that the matter is composed of atoms, such as the foundation stone to build.

At the beginning of the nineteenth century were (Dalton) put his idea of building material, saying that atom is the smallest particles of material involved in a chemical reaction. The atoms are very fine particles is impossible for a person to see even with the most powerful microscopes and diameter of atom a millionth part of a millimeter. Then came the Italian scientist (Avogadro) and the latest development on the idea of Dalton in building material, saying that smaller part in the matter can be found in private may consist of more than one atom called molecule and if contained from similar atoms is an element, either if it contains different atoms is compound. Thus became the concept of the molecule as a smaller part of the matter holds the properties of that substance.

Atom Consists from the nucleus in the center and number of electrons moving in (Shells) away very large relatively from the nucleus, nucleus consisting of particals which are protons, neutrons

The nucleus of the atom mass approximately 99.9 % of the mass of the atom and this means that most of the mass of atom almost concentrated in the nucleus.

Table 1-1 shows the names and symbols of important elements that you need them during your study of the chapters of this book.

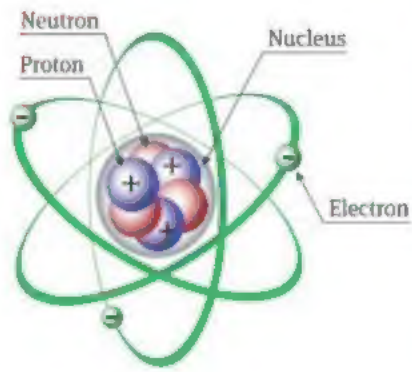
1-2 The Names and Symbols of Some Elements

Dear Student Had previously identified the names and symbols of some elements in the previous phase, and its importance in the study of chemistry to learn these elements

Symbol	Name	Symbol	Name
O	Oxygen	H	Hydrogen
Al	Aluminum	He	Helium
Ar	Argon	N	Nitrogen
Be	Beryllium	Ne	Neon
B	Boron	Mg	Magnesium
K	Potassium	Ca	Calcium
Si	Silicon	C	Carbon
Na	Sodium	Cl	Chlorine
P	Phosphorus	S	Sulfur
F	Fluorine	Li	Lithium

1-3 STRUCTURE OF ATOMS

Atom consists of the following parts:



1-3-1 Nucleus

An atom is the smallest particle that can be obtained by chemical means. One part of an atom is the central core, called the nucleus. Around the nucleus is a sphere or cloud of negative charges. Scientist have made some machines that can split atoms into even smaller particles. These particles cannot be studied by chemists. Scientists have found more than one hundred smaller, or subatomic particles. Chemists are usually concerned with only three of these particles: electron, proton and neutron.
The nucleus contains two types of subatomic particles:

A- Protons P^+

One of the two kinds of subatomic particles that make the nucleus is the proton. A proton has a mass more than 1840 times larger than an electron. Yet the proton is still very small. The mass of more than 6x1023 protons is about 1 gram. Protons are positively charged. The positive charged of one proton has the same size as the negative charge of one electron. Another name of the number of protons contained in the nucleus of an atom is called as atomic number, so we can say that:

Atomic number = Number of protons

B- Neutrons n^0

Another subatomic particle in the nucleus is the neutron. A netron has about the same mass as a proton. So neutrons, like protons, tend to make the nucleus very heavy. **Neutrons with protons in nucleus they make up most of the mass of the atom** As its name suggests, the neutron is neutral. It carries no electric charge. Neutron is symbolized by n. Mass number, A is called the total number of protons and neutrons contained in the nucleus of an atom:

Mass number = number of protons + number of neutrons

Symbolizing the mass number by A and the number of protons which is the atomic number of the element by p and the number of neutrons are indicated by n, so we can write the relation between them as in the following manner:
The mass number (A) = number of protons (p) + number of neutrons (N)

or

The mass number (A) = atomic number (Z) + number of neutrons (N)

or

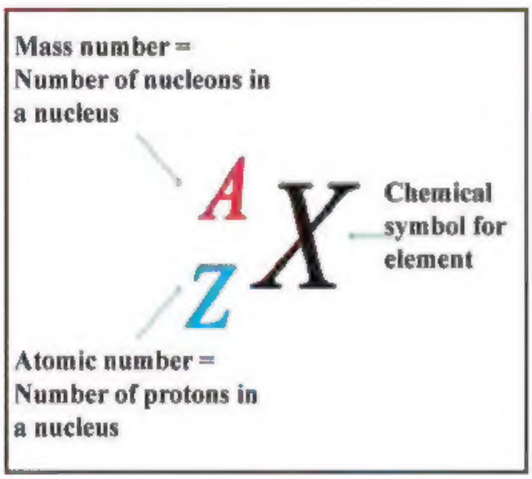
$$A = Z + N$$

To get the number of neutrons via atomic number and mass number the following relation is used :

$$N = A - Z$$

Important!!!

Let X be a symbol of any element, than the mass number, A of this element is written to the up left of the symbol, the number protons, p or atomic number, Z of the element is written to the left down corner of the symbol as follows;



Example 1-1

If you know that the atomic number of carbon, C is 6 and its mass number is 12. Find the number of neutrons in carbon atom.

Solution:

A = 12 and Z = 6

So by using the relation **N = A - Z**

N = 12 - 6

N = 6 is the number of neutrons

Table 1-2 shows the symbols of some elements, their atomic numbers, mass numbers and the number of neutrons in the nuclei of these atoms.

Number of neutrons (n)	mass number (A)	Atomic number (Z)	Symbol
12	23	11	$^{23}_{11}Na$
16	31	15	$^{31}_{15}P$
7	14	7	$^{14}_{7}N$
20	39	19	$^{39}_{19}K$
10	20	10	$^{20}_{10}Ne$

1-3-2 ELECTRONS

The first part of an atom to be discovered was the electron. An electron has negative charge. Its mass is almost zero. If $1x10^{29}$ electrons were put together they would have a total mass of only about 1 gram. The negatively charged electrons are located outside the tiny, heavy, positively charged nucleus. Electrons move around the nucleus at very high speed.

Exercise 1-1

If you know that the atomic number of chlorine, Cl is equal to 17 and mass number is 35, find the number of neutrons in the nucleus of an atom of this element.

Most of the space in an atom is filled by the negatively charged electrons. Imagine an atom to be the size of a large football stadium. The nucleus would be the size of a pea in the size of the field. Almost all the mass of the atom is concentrated in the nucleus.

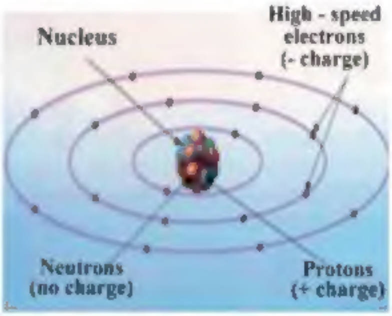
Electrons in an atom are arranged in different orbits called energy levels or shells. Number of shells in an atom are shown by n. Volumes of energy levels change according to their distances to the nucleus, and shells are symbolized

by capital letters such as K (n = 1), L (n = 2), M (n = 3), N (n = 4),...etc. beginning from the closest orbit to the nucleus. In an ordinary atom, there are always exactly the same number of protons and electrons. The negative and positive charges are balanced. Therefore, the atom has no overall charge.

Subatomic Particle	Symbol	Charge	Mass (g)	Location in the atom
Proton	p^+	+1	1.67×10^{-24}	Nucleus
Neutron	n^0	0	1.67×10^{-24}	Nucleus
Electron	e^-	-1	9.11×10^{-28}	Around the nucleus on the energy levels.

1-4 BOHR THEORY

The Bohr model, introduced by Niels Bohr in 1913, depicts the atom as small, with a positively charged nucleus surrounded by electrons that travel in circular orbits around the nucleus - similar in structure to the solar system.



The Bohr atom

Bohr worked on hydrogen atom because it is the simplest atom and left a lot of conclusions that formed the basis of his theory of the hydrogen atom and we will study this theory in detail in the coming academic years. In this chapter, we will shortly deal with two following assumptions of Bohr's Atomic Theory;

A- Electrons in atoms orbit around the nucleus.

B- The energy of the orbital is related to its size. The lowest energy is found in the smallest orbit which means the closest energy level (n = 1) to the nucleus has the lowest energy.

1-5 ARRANGEMENT OF ELECTRONS ON THE SHELLS

Electrons in an atom are arranged in different orbits called energy levels or shells. The first energy level have no more than two electrons. This is the closest level to the nucleus. The second energy level can hold up to eight electrons. The third energy level can contain a maximum number of 18 electrons. Higher energy levels sometimes hold as many as 32 electrons.

The energy levels for atoms and the number of electrons they can hold are found by using the following rules;

1) Total number of energy levels in the atom is the n.
2) Total number electrons found in the atom is calculated by $2n^2$.

Example:

The formula $2n^2$ is used to find the total number of electrons in each energy level. n stands for the number of energy level For the first energy level, K, n=1 therefore number of electrons in the first energy level = $2 \times 1^2 = 2$
For the second energy level, L, n = 2 therefore number of electrons in the second energy level = $2 \times 2^2 = 8$
For the third energy level, M, n = 3 therefore number of electrons in the third energy level = $2 \times 3^2 = 18$

If any element has full of energy levels with electrons, this means that element is stable and called as noble gas.

All of the elements want to have the same electron arrangement with noble gases. They do this by loosing or gaining electrons.

It goes on like this...

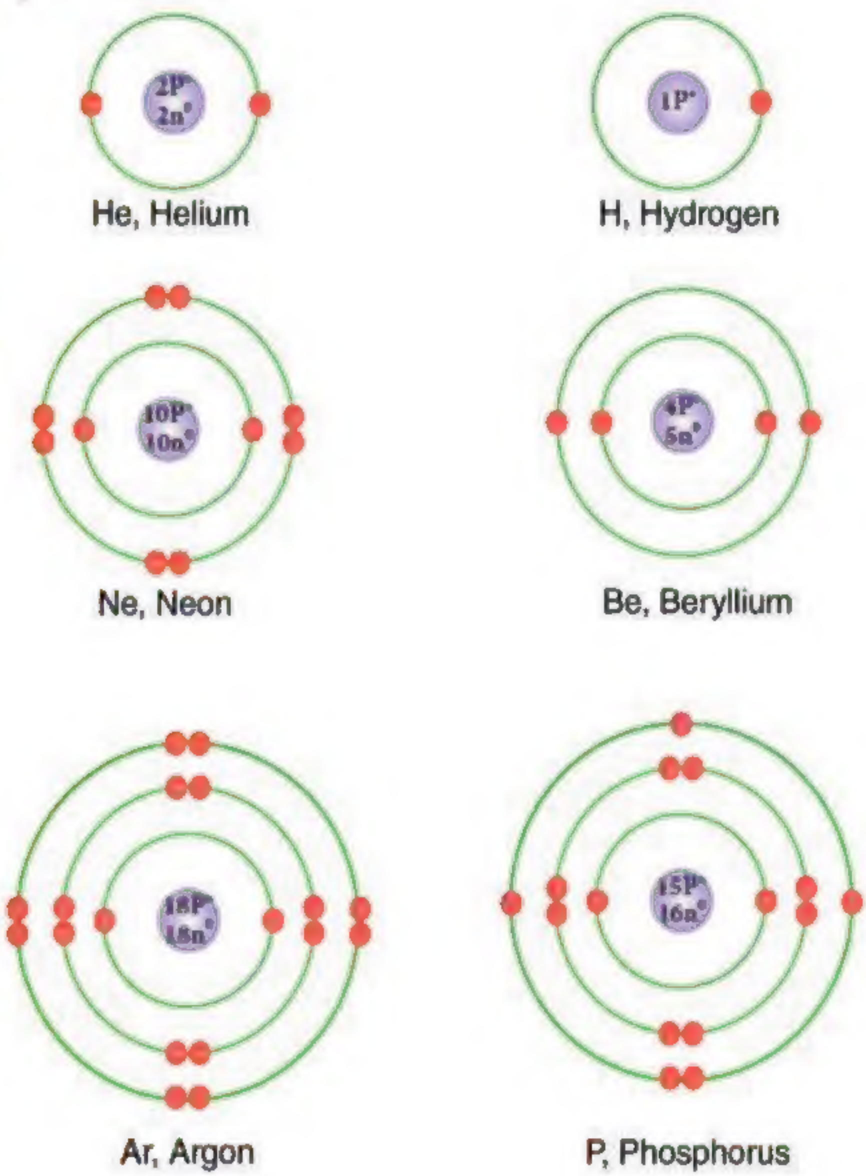


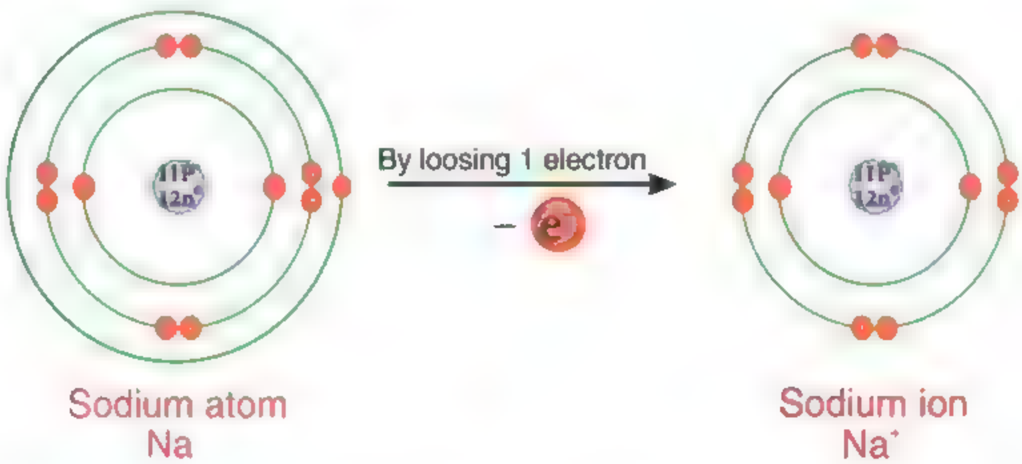
Figure 1-2
Electron arrangements of some noble gases and elements.

1-6 IONS

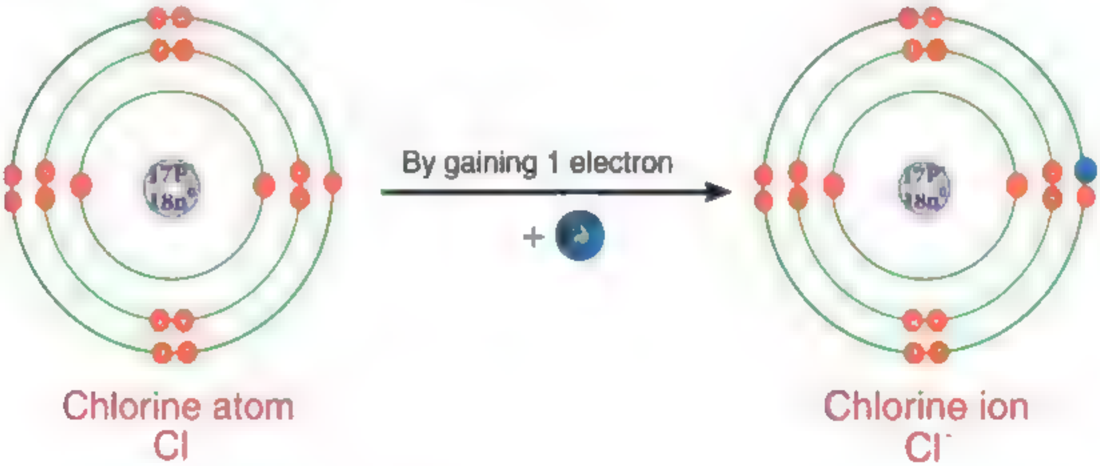
Atoms of an element are neutral particles. Their number of protons and electrons are equal. Therefore, the charge of a neutral atom is zero.

Otherwise, the atom is charged. Charged atoms are simply called ions. There are two types of ions: cations and anions.

If the number of protons is greater than the number of electrons in an atom, it is called a cation such as Na^+, Ca^{2+}, Al^{3+} and NH_4^+.



Or, if the number of protons is less than the number of electrons in an atom, it is called as anion such as Cl^-, O^{2-}, N^{3-} and SO_4^{2-}.



The comparison of atom and ion:

An atom can be an ion, but not all ions are atoms. There are distinct differences between an atom and an ion.

An atom is the defining structure of an element. Elemental atoms differ from each other by the number of protons in their nucleus.

For example, one way to distinguish oxygen atoms from nitrogen atoms would be to count the number of protons each atom has. Oxygen will have eight where nitrogen will have seven.
Atoms have the same number of electrons as the number of protons. These electrons form orbitals around the nucleus and cause much of the chemical properties of the element. When an atom's outermost orbital gains or loses electrons (also known as valence electrons), the atom forms an ion which are more stable than atoms.
Ions are atoms or molecules that have gained or lost one or more of their valence electrons and have a net positive or negative charge.

Example 1-2

Draw the electron arrangement of an atom of Lithium element and its ion.
Atomic number = 3 and mass number = 7

Solution:

Lithium atom Li 2,1

Lithium ion Li^+ $[2]^+$

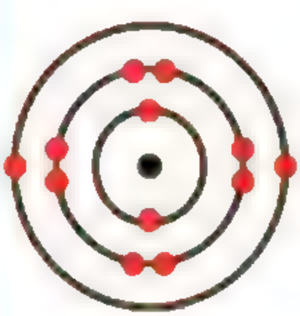
Lithium atom, Li	Lithium ion, Li^+
$e^- = 3$	$e^- = 2$
$p^+ = 3$	$p^+ = 3$
$n^0 = 4$	$n^0 = 4$

Lithium ion, Li^+. It looks like electron arrangement of Helium atom.

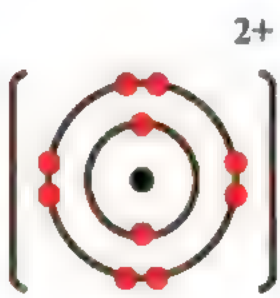
Example 1-3

Draw the electron arrangement of an atom of Magnesium element and its ion.
Atomic number = 12 and mass number = 24

Solution:



magnesium atom, Mg 2,8,2



magnesium ion Mg^{2+} $[2,8]^{2+}$

Magnesium atom, Mg	Magnesium ion, Mg^{2+}
$e^- = 12$	$e^- = 10$
$p^+ = 12$	$p^+ = 12$
$n^0 = 12$	$n^0 = 12$

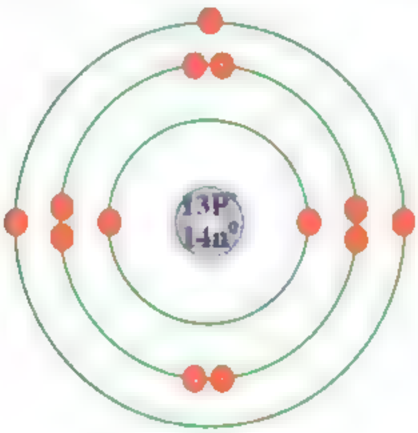
Magnesium ion, Mg^{2+}. It looks like electron arrangement of Neon atom.

Example 1-4
Draw the electron arrangement of an atom of Aluminum element and its ion.
Atomic number = 13 and mass number = 27

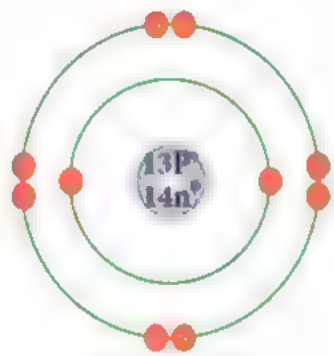
Solution:

Aluminum atom, Al
$e^- = 13$
$p^+ = 13$
$n^0 = 14$

Aluminum ion, Al^{3+}
$e^- = 10$
$p^+ = 13$
$n^0 = 14$



Aluminum atom



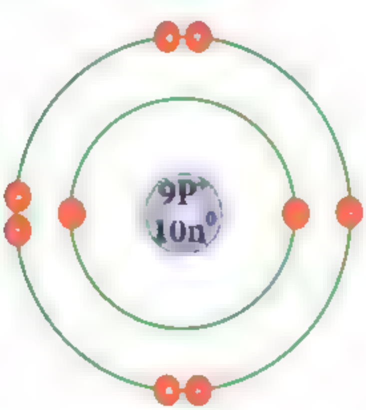
Aluminum ion, Al^{3+}
It looks like electron arrangement of Neon atom.

Example 1-5
Draw the electron arrangement of an atom of fluorine element and its ion.
Atomic number = 9 and mass number = 19

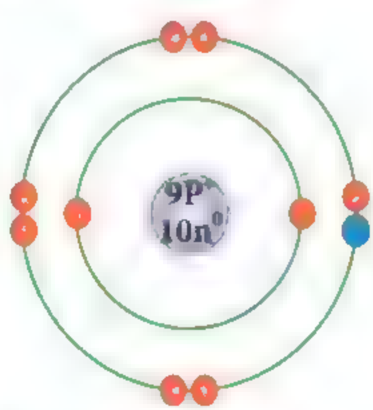
Solution:

Fluorine atom, F
$e^- = 9$
$p^+ = 9$
$n^0 = 10$

Fluorine ion, F^-
$e^- = 10$
$p^+ = 9$
$n^0 = 10$



Fluorine atom, F



Fluorine ion, F^-
It looks like electron arrangement of Neon atom.

Exercise 1-2
If you know that the atomic number of Beryllium, Be is equal to 4 and mass number is 9, draw the electron arrangement of the atom and its ion.

Exercise 1-3
Draw the electron arrangement of an atom of potassium (K) element and its ion.
Atomic number = 19 and mass number = 39.

Exercise 1-4
Draw the electron arrangement of an atom of Chlorine (Cl) element and its ion.
Atomic number = 17 and mass number = 35.

Exercise 1-5

Draw the electron arrangement of an atom of sulfur (S) element and its ion.

Atomic number = 16 and mass number = 32.

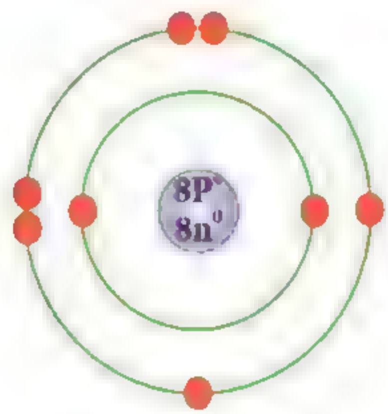
Example 1-6

Draw the electron arrangement of an atom of oxygen element and its ion.

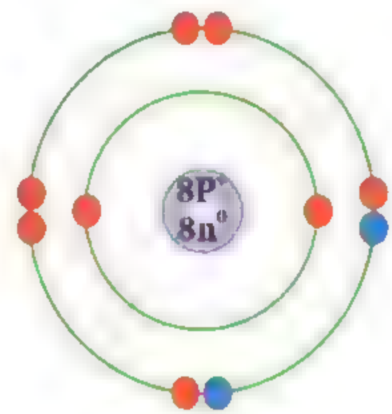
Atomic number = 8 and Mass number = 16

Solution:

Oxygen atom, O	Oxygen ion, O^{2-}
$e^- = 8$	$e^- = 10$
$p^+ = 8$	$p^+ = 8$
$n^0 = 8$	$n^0 = 8$



Oxygen atom, O



Oxygen ion, O^{2-}. It looks like electron arrangement of Neon atom.

Exercise 1-6

Draw the electron arrangement of an atom of phosphorus (P) element and its ion.

Atomic number = 16 and mass number = 32.

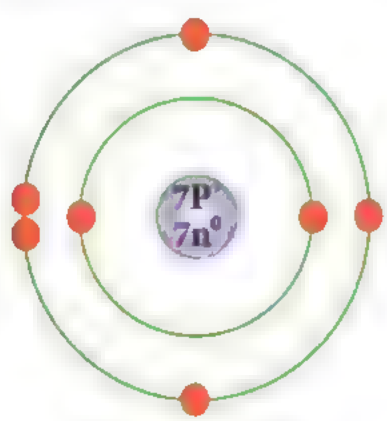
Example 1-7

Draw the electron arrangement of an atom of nitrogen element and its ion.

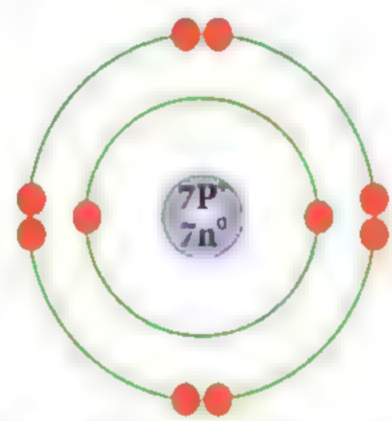
Atomic number = 7 and Mass number = 14

Solution:

Nitrogen atom, N	Nitrogen ion, N^{3-}
$e^- = 7$	$e^- = 10$
$p^+ = 7$	$p^+ = 7$
$n^0 = 7$	$n^0 = 7$



Nitrogen atom, N



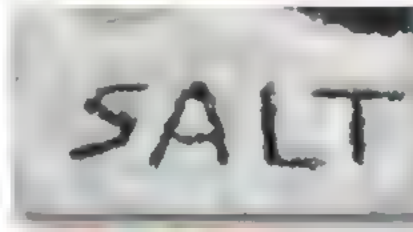
Nitrogen ion, N^{3-}. It looks like electron arrangement of Neon atom.

As we understand from the above examples, when atoms ionize, they lose their characteristic properties. The properties of lithium ion (Li^+), magnesium ion (Mg^{2+}), fluoride ion (F^-) and oxygen ion (O^{2-}) are different than the properties of lithium atom (Li), magnesium atom (Mg), fluorine atom (F) and oxygen atom (O), respectively. Because the last energy levels of these ions are full of electrons.

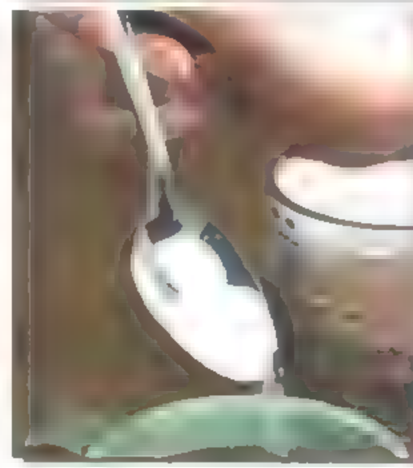
Generally, atoms of metallic elements tend to lose electrons and change into cations. While nonmetallic atoms tend to gain electrons and change into anions. It must be noted that the atoms of Noble gases such as Helium, Neon and Argon do not need to lose or gain electrons and thus not be ions under normal conditions. Because the last energy level of Noble gases are full of electrons.

1-7 CHEMICAL BONDING

Take a look at your pencil. How many different materials can you see in the pencil? You can easily see five different materials in just one simple pencil. These substances are graphite, wood, paint, rubber eraser, and the metal that holds the eraser on. If you try to list all the different substances around you, the list will be endless.



Chemists know that there are hundreds of thousands of different substances. Two of these substances are table salt and tea sugar. Salt helps the nerves of the body to function and it is used to improve the taste of the food. Sugar is added to food as sweetener. And it is an energy-giving substances. These two white solids have very different properties.



How can these different properties be explained?

The atoms in salt and sugar, however, combine together in very different ways. Almost all atoms tend to join together with other atoms. The noble gases (helium, neon, argon,... etc) are the exception to this. These gases are inert meaning unreactive. They are found in the form of only isolated single atoms.

The behavior of noble gases can be explained by the arrangement of their electrons in energy levels. The arrangement of electrons in energy levels is called **electronic configuration**. The electronic configurations of some noble gases are as in the figure 1-3.

The atoms with full shell of electrons have special stability. Noble gas atoms are very stable. Atoms of other elements do not have full shells of electrons. Then, elements tend to gain, lose, or share electrons to have full shells of electrons. As a result chemical bonding occurs. **Chemical bonds are strong forces of attraction between atoms.** There are two types of chemical bonds.

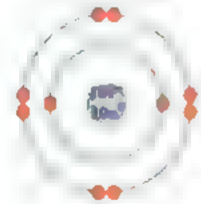
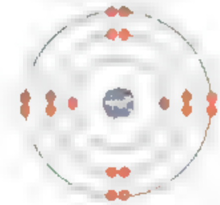
Name	Helium (He)	Neon (Ne)	Argon (Ar)
			
Electronic configuration	2	2, 8	2, 8, 8
	The first shell can hold a maximum of two electrons	The second shell can hold a maximum of eight electrons	The third shell can hold up to eight electrons
	In helium, the first shell is full	In neon, the second shell is full	In neon, the third shell is full

Figure 1-3
Electronic configurations of some noble gases.

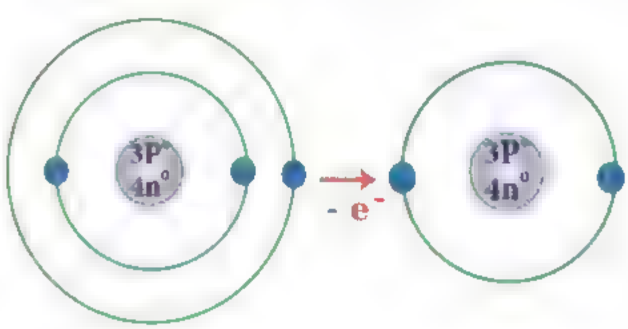
1-7-1 IONIC BONDING

An ionic bond is a type of chemical bond formed through an electrostatic attraction between two oppositely charged ions. Ionic bonds are formed between a cation, which is usually a metal, and an anion, which is usually a non-metal.

A formation of an ionic bond proceeds when the atom of an element (usually metal) releases some of its electron(s) to achieve a stable electron configuration and after releasing some of its electron(s) the atom becomes a cation. The atom of another element (usually non metal) then accepts the electron(s), again to attain a stable electron configuration and after accepting electron(s) the atom becomes an anion. Typically, the stable electron configuration is one of the noble gases for elements. The electrostatic attraction between these two entities forms the ionic bond.

A- Ionic bonding between lithium and fluorine atoms:

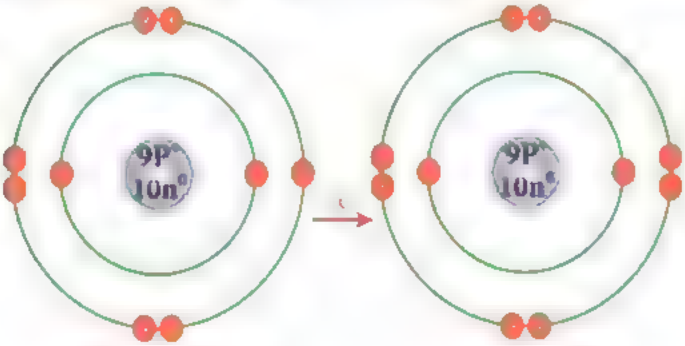
When lithium element, Li with fluorine element, F form lithium fluoride compound, LiF, the formation of ionic bonding between these elements proceeds as follows:
Electron arrangement for a lithium atom (atomic number = 3) and lithium-ion is:



Lithium atom Li

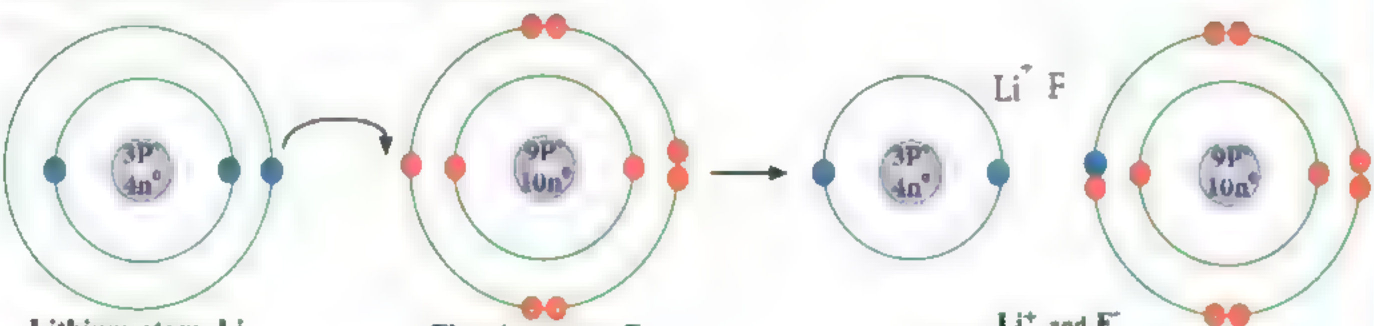
Lithium ion Li^+

In other words, there is one electron in the outer shell of an atom lithium, if lithium atom loses this electron and new electron arrangement will be similar to the electron arrangement of helium atom at the same time lithium atom becomes lithium ion, Li^+ while electron arrangement of fluorine atom, F (atomic number = 9) and fluoride ion, F^- are as follows:



Fluorine atom F **Fluorine ion** F

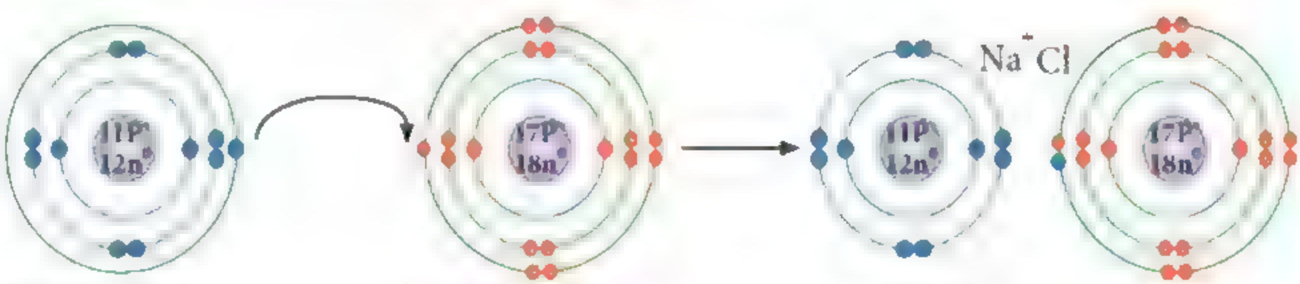
When lithium and fluorine react together, the lithium atom loses one electron and the fluorine atom gains one electron. An atom that loses one or more electrons gains a positive charge. In this case, lithium atom has 3 protons and 2 electrons. The overall charge is (+1). Then, a positively charged ion, called **cation**, is formed. If an atom gains electron(s), negatively charged ion, called **anion**, is formed. The net charge is written to the upper right of the symbol for the element. The newly formed lithium (Li^+) and fluoride (F^-) ions attract each other. This is known as **electrostatic attraction.**



Lithium atom, Li **Fluorine atom, F** **Li^+ and F^-** **LiF Ionic compound**

B- Ionic bonding between sodium and chlorine atoms

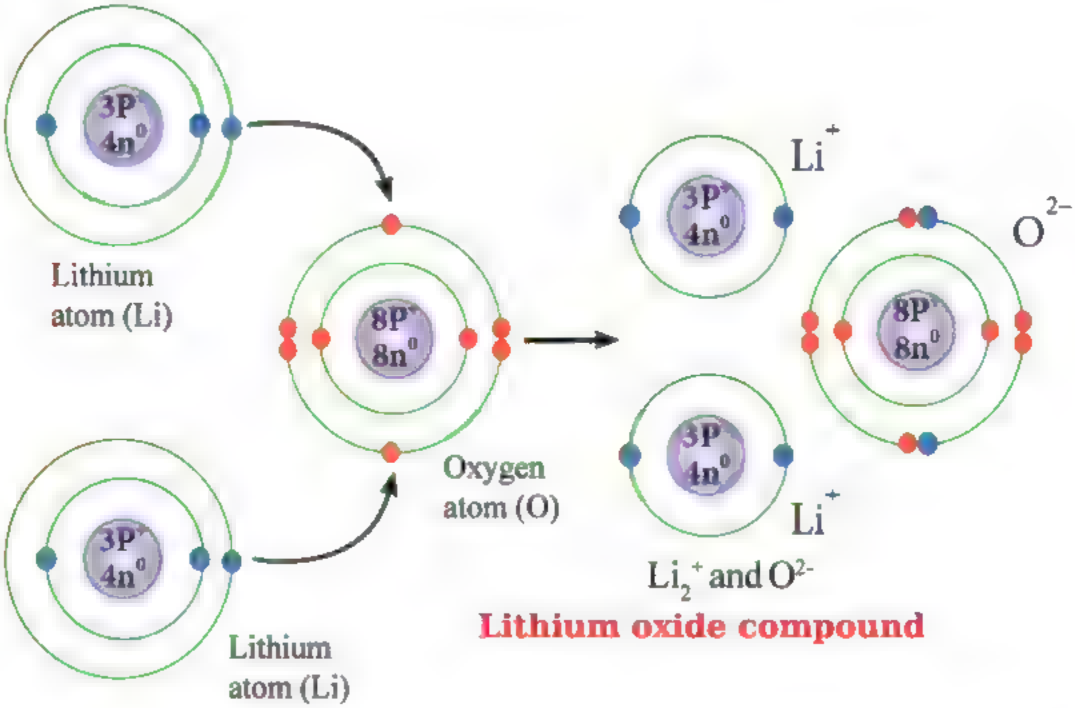
When sodium atom, Na (atomic number = 11) and chlorine atom, Cl (atomic number = 17) are bonded to form an ionic compound that is sodium chloride, NaCl, this bonding can be illustrated by the following figure.



Sodium atom, Na **Chlorine atom, Cl** **Na^+ and Cl^-** **NaCl Ionic compound**

C- Ionic bonding between lithium and oxygen atoms:

When lithium atom, Li (atomic number = 3) and oxygen atom, O (atomic number = 8) are bonded to form an ionic compound that is lithium oxide, Li_2O, this bonding can be illustrated by the following figure.



Li_2^+ and O^{2-}

Lithium oxide compound

Exercise 1-7

Draw the figure which shows the ionic bonding between $_{19}K$ and $_{17}Cl$ atoms to form potassium chloride, KCl that is an ionic compound.

Exercise 1-8

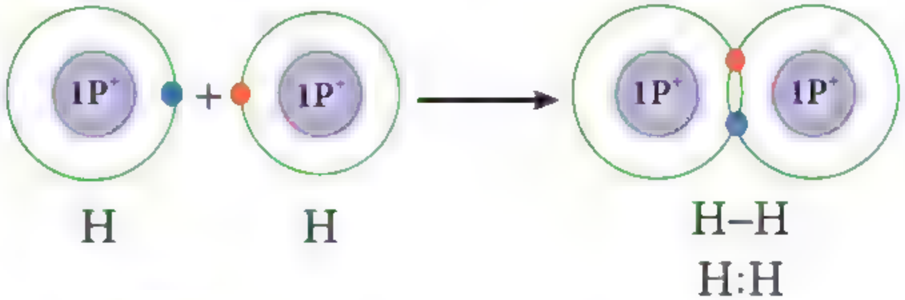
Draw the figure which shows the ionic bonding between $_{11}Na$ and $_{8}O$ atoms to form sodium oxide, Na_2O that is an ionic compound.

This shows that oxygen atom has six electrons in its last shell and needs only two electrons to fill it. Therefore oxygen atom is bonded to two lithium atoms. Because both of lithium atoms consist of 2 single electrons in their last energy levels that can be transferred easily.

1-7-2 COVALENT BONDING

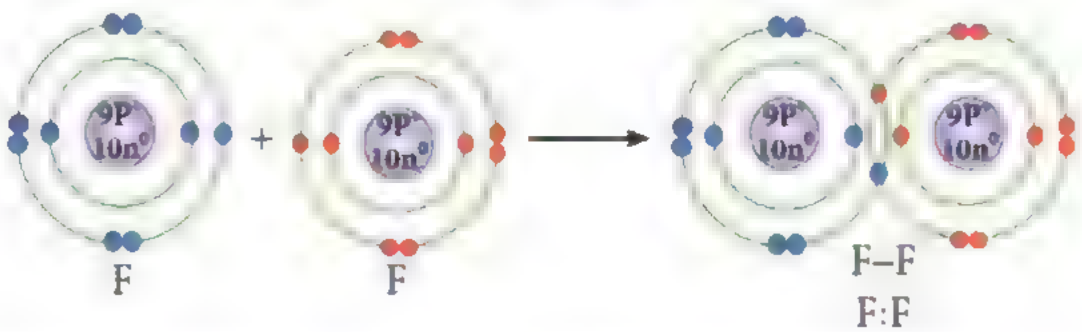
A covalent bond is the chemical bond that involves the sharing of pairs of electrons between atoms. The stable balance of attractive and repulsive forces between atoms when they share electrons is known as covalent bonding. For many molecules, the sharing of electrons allows each atom to attain the equivalent of a full outer shell, corresponding to a stable electronic configuration.

For example, hydrogen has one electron in its outer shell. So it is one electron short of a full outer shell. One way it can be filled is by joining with another hydrogen atom, and sharing electrons.



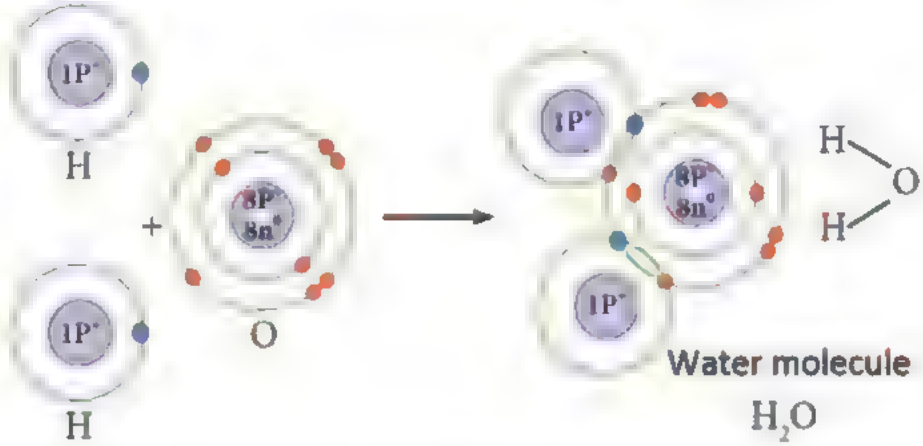
By sharing electrons in a such way, both fill their outer energy levels. Now, each hydrogen atom has two electrons in its first energy level. This completes the first energy level. Element hydrogen exists as diatomic molecules like H_2. Some common gases, such as hydrogen, oxygen, fluorine, and nitrogen have diatomic molecules. The bonds that hold together the atoms in these molecules are covalent bonds.

Another example is covalent bonding between two fluorine atoms (atomic number of Fluorine = 9). Fluorine has seven electrons in its outer shell. So it is one electron short of a full outer shell. There is only one way for filling its outermost shell is by joining with another fluorine atom, and sharing electrons.



By sharing electrons in a such way, both fill their outer energy levels. Now, each fluorine atom has seven electrons in its third energy level. This completes the third energy level. Element fluorine exists as diatomic molecules like F_2. The bond that holds fluorine atoms together in this molecule is covalent bond.

One more example for covalent bonding is the bonding between two hydrogen atoms (atomic number = 1) and one oxygen (atomic number = 8) to form water, H_2O compounds. To fill the last energy level of oxygen atom, we need two electrons and these two electrons can be obtained by sharing from each of two hydrogen atoms. Because each hydrogen atom contains one electron in its last energy level. Examine the following figure;



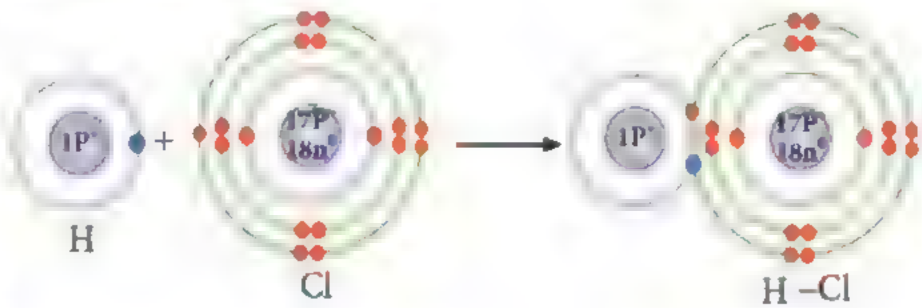
H_2O

Last example for covalent bonding is the bonding between one hydrogen atom (atomic number = 1) and one chlorine atom (atomic number = 17) to form hydrogen chloride, HCl compound. Chlorine has seven electrons in its outer

Exercise 1-9
Show the covalent bonding in chlorine molecule (Cl_2) which is formed from combination of 2 chlorine atoms.
Atomic number: 17

Exercise 1-10
Show the covalent bonding in ammonia molecule, NH_3 by drawing. Hydrogen has one electron in its outer energy level. Nitrogen has two electrons in its first energy level and five electrons in its second energy level.

shell. So it is one electron short of a full outer shell. Hydrogen has one electron in its outer shell. So it is one electron short of a full outer shell. Both of them need one electron to fill last energy level. There is only one way for filling their outermost shells is by sharing one electron.



1-8 VALENCY
The number of electrons found on the last energy level of the atoms is called **valency, valence** or **valence electrons** and valency determines the chemical behaviour of element. The electrons in the interior shells play a secondary role because of the effect of the existing charge in the nucleus of an atom. The valence electrons affect the behavior of atom during the formation of a chemical bond(s) between atoms.

Therefore, valence electrons can be defined as the number of lost, gained or shared electrons of atoms obtained during the chemical reactions.

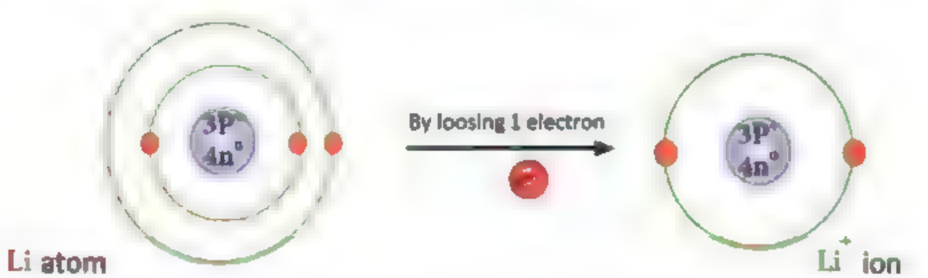
Valency is beneficial in writing chemical formulas (we will see later).

To find the valency of an atom, the following rules must be applied:

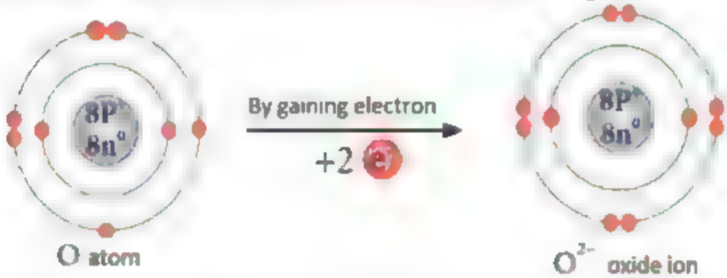
1- The number of electrons in the outer shell and whether the shell is full or not must be known.

2- The number of electrons which would be lost, gained or shared by the atoms to fill their last shells must be known. During the formation of a chemical bond between atoms, the last shell plays a great role. Because electrons used to form the bond(s) are transferred or shared from the last shell of the atoms. So, the electrons which are found at the last energy level in an atom are called as **valence electrons.**

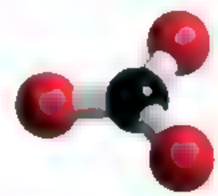
For example; lithium atom (atomic number is 3) contains one valence electron, so lithium atom tends to lose this one electron during the formation of chemical bonding. After loosing that one electron from its outermost shell, it changes into lithium ion, Li^+. Lithium is considered as a univalent element.



An oxygen atom (Z=8) contains six valence electrons. Therefore, oxygen atom tends either to gain or to share two electrons with another atom(s) to form two bonds. At the end of this, oxygen atom completes its last energy level with eight electrons. This is what we want because all the atoms want to saturate its valence shell to have the full shell as in the noble gases.



A polyatomic ion is known as a molecular ion, is a charged species (ion) composed of two or more atoms covalently bonded to each other.
The polyatomic ions such as hydroxide ion, OH^-, ammonium ion, NH_4^+, divalent carbonate ion, CO_3^{2-} and sulfate ion, SO_4^{2-} and trivalent phosphate ion, PO_4^{3-} have valency. They can be considered to be acting as a single unit in the formation of compounds.



carbonate ion, CO_3^{2-}

1-9 OXIDATION NUMBER AND CHEMICAL FORMULA

The total number of natural and synthetic chemical compounds runs in the millions. For some of these substances, certain common names remain in everyday use. For example, calcium carbonate is better known as limestone, and sodium chloride is usually referred to simply as table salt. And everyone recognizes dihydrogen monoxide by its popular name, water.
Unfortunately, common names usually give no information about chemical composition. To describe the atomic makeup of compounds, chemists use systematic methods for naming compounds and for writing chemical formulas. In this chapter, you will be introduced to some of the rules used to identify simple chemical compounds.

1-9-1 Significance of a Chemical Formula

The formula for a compound is a shorthand way of writing the name for a compound. The chemical symbols that are assigned to the elements are used to write formulas. A chemical formula is a symbolic representation of

1. The elements present in a compound.
2. The relative numbers of atoms of each element.

Consider the following formulas. The element present are denoted by their symbols and relative numbers of atoms by subscript numerals.

When there is no subscript written next to an atom's symbol, the value of the subscript is understood to be 1.

C_8H_{18}

Subscript indicates that there are 8 carbon atoms in a molecule of octane.

Subscript indicates that there are 18 hydrogen atoms in a molecule of octane.

$Al_2(SO_4)_3$

Subscript 2 refers to 2 aluminum atoms.

Subscript 4 refers to 4 oxygen atoms in sulfate ion.

Subscript 3 refers to everything inside parentheses, giving 3 sulfate ions, with a total of 3 sulfur atoms and 12 oxygen atoms.

Important!!!

Atoms are the building blocks of elements. Molecules are the building blocks of compounds. The only difference between atoms and molecules is that chemically bonded different atoms form the molecules. But molecules of divalent compounds are formed by bonding the same atoms.

As shown above, the subscripts of the formula indicate the relative numbers of atoms of each type that are combined. If a symbol carries no subscript, the number 1 is accepted.

For example: the formula of sulfuric acid, H_2SO_4, indicates that two atoms of hydrogen, one atom of sulfur and four atoms of oxygen are contained in a formula unit of sulfuric acid. Formulas used to show the atomic composition of some elements.

The number in front of a symbol or formula is called a **coefficient.**

$2\,H_2O$

Subscript

Coefficient

In the above example, it is the formula of water which contains four hydrogen atoms and two oxygen atoms.

Example 1-10

How many atoms are found in the following formulas?

a) $2HCl$

b) $(NH_4)_2SO_4$

c) K_2SO_4

d) $5H_3PO_4$

Solution:

a) $2HCl = 2 \times 1(H) + 2 \times 1(Cl) = 4$ atoms

b) $(NH_4)_2SO_4 = 2 \times 1(N) + 4 \times 2(H) + 1(S) + 4 \times 1(O) = 15$ atoms

c) $K_2SO_4 = 2 \times 1(K) + 1(S) + 4 \times 1(O) = 7$ atoms

d) $5H_3PO_4 = 5 \times 3(H) + 5 \times 1(P) + 5 \times 4(O) = 40$ atoms

Exercise 1-11

How many atoms does each of the following compounds consist of?

a) $Ba(OH)_2$

b) $3Fe_2O_3$

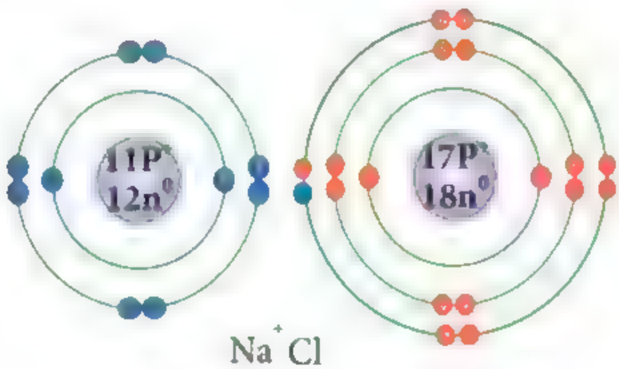
c) $5Li_2CO_3$

d) $10H_2S$

e) $(NH_4)_2CO_3$

f) $5MgBr_2$

By gaining or losing electrons, many elements form ions with noble gas configurations. For example, some elements lose one electron to give +1 cations, such as Na^+.

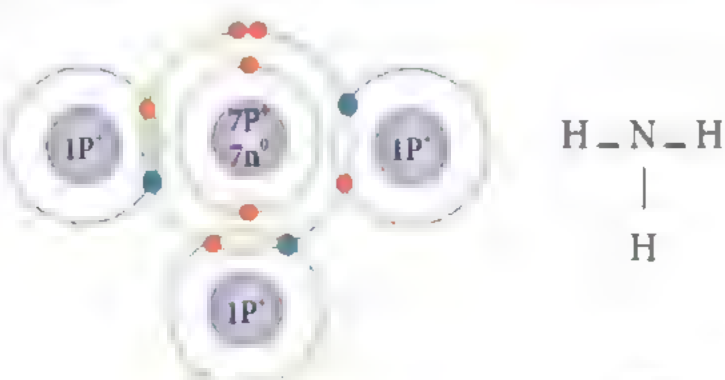


Formula of sodium chloride, NaCl

Important!!!

Oxidation number is the number of electrons gained or lost by any atom during the formation of a chemical bond. It can be either a positive integer number or a negative integer number.

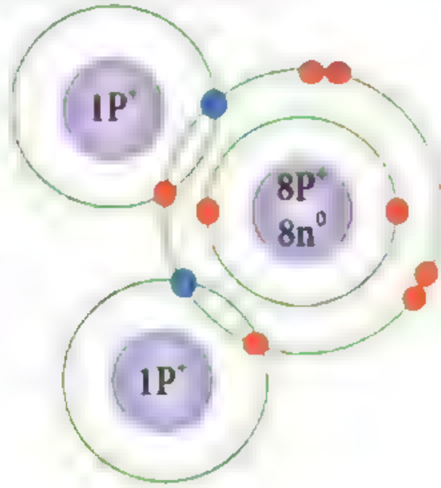
Some elements lose two electrons to give +2 cations, such as Mg^{2+}. Ions formed from a single atom are known as **monatomic ions**. Some elements gain electrons to form anions. For example, in ionic compounds nitrogen forms the -3 anion, N^{3-}. The three added electrons plus the five outermost electrons in nitrogen atoms give a completed outermost shell as shown in the following figure.

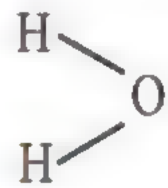


Important!!!

If any atom loses electron(s), atom will be positively charged, and if any atom gains electron(s), atom will negatively charged.

Similarly, oxygen and sulfur elements form 2− anions, and fluorine, chlorine, bromine elements form 1− anions.





Other elements tend to form ions that do not have noble-gas configurations. For instance, it is difficult for tin and lead to lose four electrons to form 4+ cations and to achieve a noble-gas configuration.

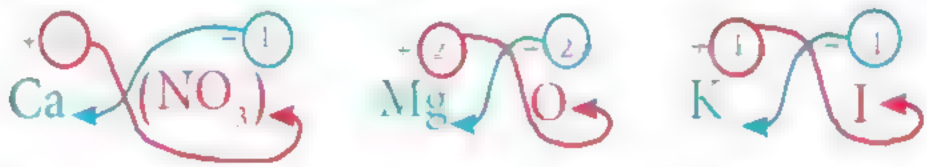
Oxidation Number	Species	Oxidation Number	Species
+1	Potassium (K^+)	+2	Mercury (II) (Hg^{2+})
+1	Sodium (Na^+)	+2	Tin (II) (Sn^{2+})
+1	Silver (Ag^+)	+2	Magnesium (Mg^{2+})
+1	Copper (I) (Cu^+)	+2	Calcium (Ca^{2+})
+1	Hydrogen (H^+)	+2	Zinc (Zn^{2+})
+1	Ammonium (NH_4^+)	+2	Barium (Ba^{2+})
-1	Chloride (Cl^-)	+2	Iron (II) (Fe^{2+})
-1	Bromine (Br^-)	+2	Copper (II) (Cu^{2+})
-1	Hydroxide (OH^-)	+2	Lead (II) (Pb^{2+})
-1	Nitrate (NO_3^-)	-2	Carbonate (CO_3^{2-})
-1	Nitride (NO_2^-)	-2	Sulfate (SO_4^{2-})
-1	Chlorate (ClO_3^-)	-2	Sulfide (S^{2-})
-1	Iodide (I^-)	-2	Oxide (O^{2-})
-1	Fluoride (F^-)		
Oxidation Number	**Species**	**Oxidation Number**	**Species**
+3	Aluminum (Al^{3+})	+4	Lead (IV) (Pb^{4+})
+3	Iron (III) (Fe^{3+})	+4	Tin (IV) (Sn^{4+})
-3	Phosphate (PO_4^{3-})	+4	Manganese (IV) (Mn^{4+})

In writing the formulas for most simple compounds, the following rules are applied.

1. Cations are written first. If atoms tend to lose one or more electrons to form positive ions, they are called cations.

2. Anions are written last. If atoms tend to gain one or more electrons to form negative ions, they are called anions.

3. The net charge on the resulting compound must be zero. Thus, the charges indicated by the valence numbers must be balanced. To do this, subscripts are written to the right of the element or polyatomic ion.



4. The valence of atomic ion must equal the algebraic sum of the charges assigned to the individual atoms making up the polyatomic ion.

5. If a polyatomic ion appears more than once in the formula, it is enclosed in parentheses, and the subscript is placed just outside to the right. The formula for the compound formed between the ions X^{n+} **and** Y^{m-}, may be written $X^{n+}Y^{m-}$, X_mY_n **if |n| = |m|** then the formula is shortened to **XY**.

Important!!!

X_mY_n is a compound then n and m are positive integer numbers. n and m ∈ 1, 2, 3, 4, . . .etc.

Exercise 1-12

Write the correct formula and name of compounds formed between the following ions.

a) Na^+ and Cl^-
b) Mg^{2+} and Cl^-
c) Al^{3+} and O^{2-}
d) Mg^{2+} and N^{3-}
e) Pb^{4+} and O^{2-}
f) NH_4^+ and Br^-
g) NH_4^+ and SO_4^{2-}
i) Fe^{3+} and OH

Name of the Compound	Chemical Formula	Name of the Compound	Chemical Formula
Sodium chloride	$NaCl$	Calcium oxide	CaO
Magnesium bromide	$MgBr_2$	Aluminum oxide	Al_2O_3
Barium hydroxide	$Ba(OH)_2$	Lithium carbonate	Li_2CO_3
Barium carbonate	$BaCO_3$	Ammonium sulfate	$(NH_4)_2SO_4$
Hydrogen sulfide	H_2S	Aluminum sulfate	$Al_2(SO_4)_3$
Calcium phosphate	$Ca_3(PO_4)_2$	Dihydrogen monoxide (water)	H_2O

1-10 PERIODIC TABLE

The periodic table is a tabular display of the chemical elements, organized on the basis of their atomic numbers, electron configurations, and recurring chemical properties. Elements are presented in order of increasing atomic number (number of protons).

Since, by definition, a periodic table incorporates recurring trends, any such table can be used to derive relationships between the properties of the elements and predict the properties of new, yet to be discovered or synthesized, elements.

Although precursors exist, Dmitri Mendeleev is generally credited with the publication, in 1869, of the first widely recognized periodic table. All elements from atomic numbers 1 (hydrogen) to 118 (ununoctium) have been discovered or synthesized.

In the standard periodic table, the elements are listed in order of increasing atomic number (the number of protons in the nucleus of an atom). A new row (period) is started when a new electron shell has its first electron. Columns (groups) are determined by the electron configuration of the atom; elements with the same number of electrons in a particular subshell fall into the same columns (e.g. oxygen and selenium are in the same column because they both have four electrons in the outermost shell). Elements with similar chemical properties generally fall into the same group in the periodic table, the elements in the same period tend to have similar properties, as well. Thus, it is relatively easy to predict the chemical properties of an element if one knows the properties of the elements around it.

1-10-1 GROUPS

A group or family is a vertical column in the periodic table. Groups usually have more significant periodic trends than periods Elements within the same group generally have the same electron configurations in their valence shell. Consequently, elements in the same group tend to have a shared chemistry and exhibit a clear trend in properties with increasing atomic number.

The groups are numbered numeri cally from 1 to 18 from the leftmost column (the alkali metals) to the rightmost column (the noble gases). Previously, they were known by roman numerals.
the roman numerals were followed by either an "A" or a "B" The roman numerals used correspond to the last digit of today's naming convention (e.g. the group 4 elements were group IVB, and the group 14 elements was group IVA). Some of these groups have been given trivial (unsystematic) names,as seen in the table to the right, although some are rarely used. B Groups have no trivial names and are referred to simply by their group numbers or by the name of the first member of their group (such as 'the scandium group' for Group 3), since they display fewer similarities and/or vertical trends.

1-10-2 PERIODS

A period is a horizontal row in the periodic table. Although groups generally have more significant periodic trends, there are regions where horizontal trends are more significant than vertical group trends, such the
lanthanides and actinides form two substantial horizontal series of elements.

Periodic Table of the Elements

Periodic Table of the Elements

Groups

Atomic Number	6
Symbol	C
Name	Carbon
Average Atomic Mass	12.0107

Hydrogen
Semiconductors
(also known as metalloids)

Metals
Alkali metals
Alkaline earth metals
Transition metals
Other metals

Nonmetals
Halogens
Noble gases
Other nonmetals

Periods

Period	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
1	1 H Hydrogen 1.007 94																	2 He Helium 4.002 60
2	3 Li Lithium 6.941	4 Be Beryllium 9.012 182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.998 4032	10 Ne Neon 20.1797
3	11 Na Sodium 22.989 769 28	12 Mg Magnesium 24.3050											13 Al Aluminum 26.981 5386	14 Si Silicon 28.0855	15 P Phosphorus 30.973 762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955 912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938 045	26 Fe Iron 55.845	27 Co Cobalt 58.933 195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.409	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.921 60	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.905 85	40 Zr Zirconium 91.224	41 Nb Niobium 92.906 38	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.905 50	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.904 47	54 Xe Xenon 131.293
6	55 Cs Cesium 132.905 4519	56 Ba Barium 137.327	57 La Lanthanum 138.905 47	72 Hf Hafnium 178.49	73 Ta Tantalum 180.947 88	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966 569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.980 40	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	Uub*		Uuq*		Uuh*		

* The systematic names and symbols for elements greater than 111 will be used until the approval of trivial names by the IUPAC.

The discoveries of elements with atomic numbers 112, 114, and 116 have been reported but not fully confirmed.

58 Ce Cerium 140.116	59 Pr Praseodymium 140.907 65	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925 35	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930 32	68 Er Erbium 167.259	69 Tm Thulium 168.934 21	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
90 Th Thorium 232.038 06	91 Pa Protactinium 231.035 88	92 U Uranium 238.028 91	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

The atomic masses listed in this table reflect the precision of current measurements. (Each value listed in parentheses is the mass number of that radioactive element's most stable or most common isotope.)

CHAPTER QUESTIONS 01

1-1 Choose the correct answer for the following questions.

1) Which one of the following particals have most of the mass?

A) Proton B) Neutrons
C) Electron D) Neutrons with protons

2) Which one of the followings is not a characteristic property of a nucleus ?

A) It is positively charged
B) Has high density
C) Its mass is equal to the mass of an atom
D) Its volume is equal to the volume of an atom

1-2 Fill in the blanks with appropriate answers.

1) The region of atom that does not have electron, is ....

A) region around the nucleus
B) electron cloud
C) nucleus
D) energy levels

2) Mendeleev was a scientist who arranged the elements in the periodic table according to their ....

A) symbols
B) mass numbers
C) atomic numbers
D) electron configuration

3) In the periodic table, elements are arranged according to ....

A) decrease in their mass numbers
B) increase in their mass numbers
C) decrease in their atomic numbers
D) increase in their atomic numbers

4) If the elements are found horizontally in the same order that means they are in the same ....

A) group B) period
C) family D) civilization

5) If an atom .... one or more electron, it will be negatively charged ion.

A) loses B) gains
C) shares D) either loses,gains or shares

6) Valence electrons are the electrons that are found..

A) closely to nucleus
B) in the first shell
C) on the electronegative cloud
D) on the last energy level

7) .... occupies the greatest mass of an atom.

A) Nucleus B) Neutron
C) Electronegative cloud D) Proton

8) .... are the neutral subatomic particles and located in the nucleus.

A) Electrons B) Ions
C) Neutrons D) Protons

9) The mass of neutron is equal to the mass of .... which are made up of the nucleus.

A) proton B) electron
C) twice of a proton D) twice of an electron

10) The nucleus of many atoms are made up of ....

A) protons B) neutrons
C) protons and neutrons D) electrons

11) The atom is neutral. Because ....

A) number of neutrons and protons is equal to number of electrons.
B) energy of atom is equal to the energy of electron.
C) number of protons is equal to the number of electrons.
D) number of neutrons is equal to the number of electrons.

12) .... is the smallest particle of an element.

A) electron B) proton
C) neutron D) nucleus

1-3 Complete the sentences with appropriate answers.

1) Elements in the same column of a periodic table are located in the same ....

2) particles which are making up of the atom and having greatest mass .... and the smallest mass is ....

3) Number of protons and neutrons which are found in the .... are used to calculate the .... number.

4) For a bromine atom, Br if it mass number = 79 and atomic number = 35 then number of electrons = ... and number of neutrons = ...

1-4 Determine the following sentences are whether true or false. Then correct the incorrect sentence/ s.

1) Thought is a matter since it occupies volume in space.

2) Air is a matter since it has mass and occupies volume in space.

3) The subatomic particles which are neutral and making up of the structure of the atom, are located around the nucleus.

4) The number of electrons which are found on the shells are calculated by substracting the number of protons from mass number.

1-5 Choose the proper answer in the parentheses.

1) The second shell in an atom can maximum hold up of (2, 8, 18, 10) electrons.

2) If atom M changes into ion M^{2-} then its oxidation number will be (-2, +1, +2, +3)

3) If atom N changes into ion N^{3-} then its oxidation number will be (-1, +1, -3, +3)

4) There are (2, 4, 12, 3) oxygen atoms in compound $Al_2(SO_4)_3$.

5) The chemical formula of compound of iron (II) is (Fe_2O_3, FeO, Fe_3O_4)

6) The oxidation number of chlorine element in $CaCl_2$ is (-2, -3, -1, +1).

7) There are (2, 3, 4, 6) sodium atoms in compound $2Na_3PO_4$.

8) In nature, helium element is found in the form of (He_4, He_2, He, He_3)

9) If the oxidation number of chlorine element in the formula of $FeCl_3$ is -1, then the oxidation number of iron will be (+1, +2, +3, +4) in this compound.

1-6 A nitrogen atom and three hydrogen atoms are bonded to each other to form compound ammonia, NH_3. Show the formation of NH_3 by drawing. ($_7N$ and $_1H$)

1-7 Write the name for each of the following negatively charged ions;

1) CO_3^{2-} 2) I^- 3) ClO_3^-
4) SO_4^{2-} 5) NO_3^-

1-8 Write down the chemical formulas which will be obtained by combination of the following ions.

1) K^+ and S^{2-}
2) Cl^- and NH_4^+
3) Ca^{2+} and NO_3^-
4) Fe^{2+} and OH^-
5) Mg^{2+} and CO_3^{2-}
6) Br^- and Al^{3+}
7) Mg^{2+} and PO_4^{3-}

1-9 What will be the oxidation number of each of the following elements, if their atomic numbers are given as follows?

1) Hydrogen, atomic number = 1
2) Netrogen, atomic number = 7
3) Oxygen, atomic number = 8
4) Magnesium, atomic number = 12
5) Boron, atomic number = 5

1-10 Write the chemical formula for each of the following compounds given in word.

1) Magnesium chloride
2) Potassium oxide
3) Calcium nitrate
4) Sodium nitride
5) Hydrogen sulfide
6) Aluminum hydroxide
7) Iron (II) sulfide
8) Iron (II) sulfate
9) Ammonium sulfate

1-11 The oxidation number of metallic element M is +2, the oxidation number of non-metallic element X is -1, and the oxidation number of non-metallic element Y is -3. According to the givens which one/s is/are of the followings correct or not?

1) M_3X 2) MY 3) M_3Y 4) M_3Y_2 5) MX
6) MY_3 7) MY_2 8) M_2Y 9) M_2X

1-12 Calculate the numbers of proton and neutron for each of the following elements;

1) $^{207}_{82}Pb$, 2) $^{99}_{43}Tc$, 3) $^{226}_{88}Ra$

1-13 Write the name for each of the following positively charged ions;

1) Al^{3+} 2) H^{+}
3) Fe^{3+} 4) Fe^{2+}
5) NH_4^{+}

1-14 Complete the following equations.

1) $Na \rightarrow Na^{+} +$ ....
2) $O + 2e^{-} \rightarrow$ ....
3) $Ca \rightarrow Ca^{2+} +$ ....
4) $Cl + e^{-} \rightarrow$ ....
5) $Al \rightarrow$ .... $+ 3e^{-}$
6) $Mg \rightarrow$ .... $+ 2e^{-}$

1-15 According to the following, calculate the neutron numbers for each of them.

1) $A = 58$ and $Z = 28$
2) $A = 238$ and $Z = 92$
3) $A = 45$ and $Z = 21$
4) $A = 40$ and $Z = 18$

1-16 Na = 11, Cl = 17, Ca = 20, K = 19, F = 9,
O = 8, Mg = 12, S = 16, H = 1, C = 6.
Consider the atomic numbers of elements given above, answer the following questions.

1) Draw by showing electron arrangements of atom and ion figures for the elements which are join together to form the following compounds.

a- Calcium chloride
b- Potassium oxide
c- Calcium oxide
d- Sodium sulfide
e- Magnesium chloride

2) Draw the figures of electron arrangements for the following covalently bonded molecules.

a- Hydrogen fluoride (HF)
b- Methane (CH_4)
c- Water (H_2O)
d- Ammonia (NH_3)

1-17 How many atoms of elements are there in each of the following compounds?

1) $4Na_2SO_4$ 2) $5H_2O$ 3) $Zn_3(PO_4)_2$

1-18 If a sodium atom, Na has atomic number as 11 and mass number as 23, then draw the arrangement of electrons for sodium atom and sodium ion, respectively.

1-19 Consider the ions of the following elements whose atomic and mass numbers are given below, then fill in the table with appropriate answers.

$^{27}_{13}Al$, $^{9}_{4}Be$, $^{35}_{17}Cl$, $^{32}_{16}S$.

Ion	Z	A	Proton number	Neutron number	Electron number	Charge
Cl^-						
Be^{2+}						
S^{2-}						
Al^{3+}						

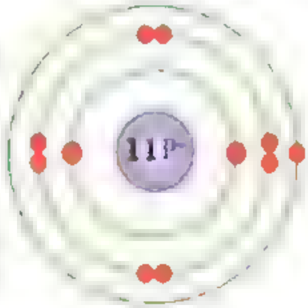
1-20 Answer the following questions considering the electron arrangements below.

1) How many valence electrons does each of sodium and chlorine atoms have?

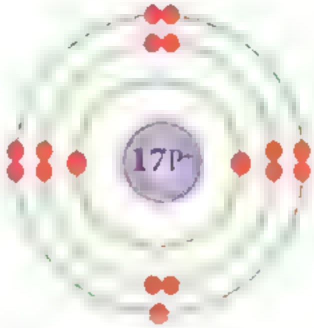
2) Which element carries negative charge and which element carries positive charge? Why?

3) What are the atomic numbers of sodium and chlorine elements?

4) How many electrons does sodium atom lose? How many electrons does chlorine atom gain? Why?



Sodium atom, Na



Chlorine atom, Cl

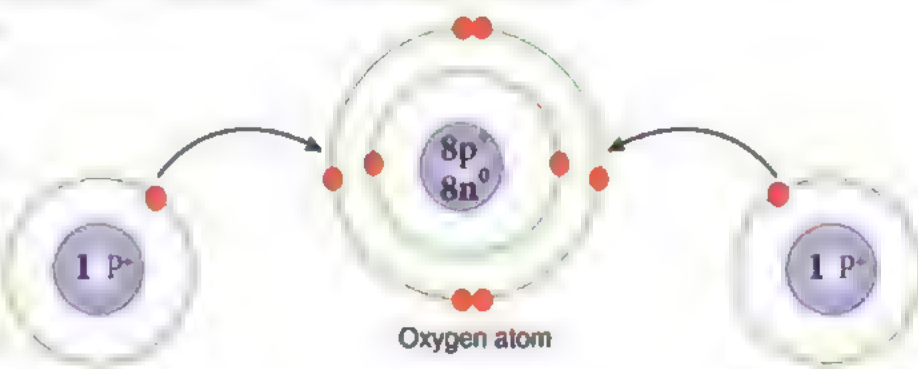
1-21 Answer the following questions considering the electron arrangements below.

1) What are the atomic numbers of oxygen and hydrogen elements?

2) How many neutrons does an oxygen atom consist of?

3) What is the mass number of oxygen atom?

4) How many electrons are there on the outermost shell of oxygen and hydrogen atoms?

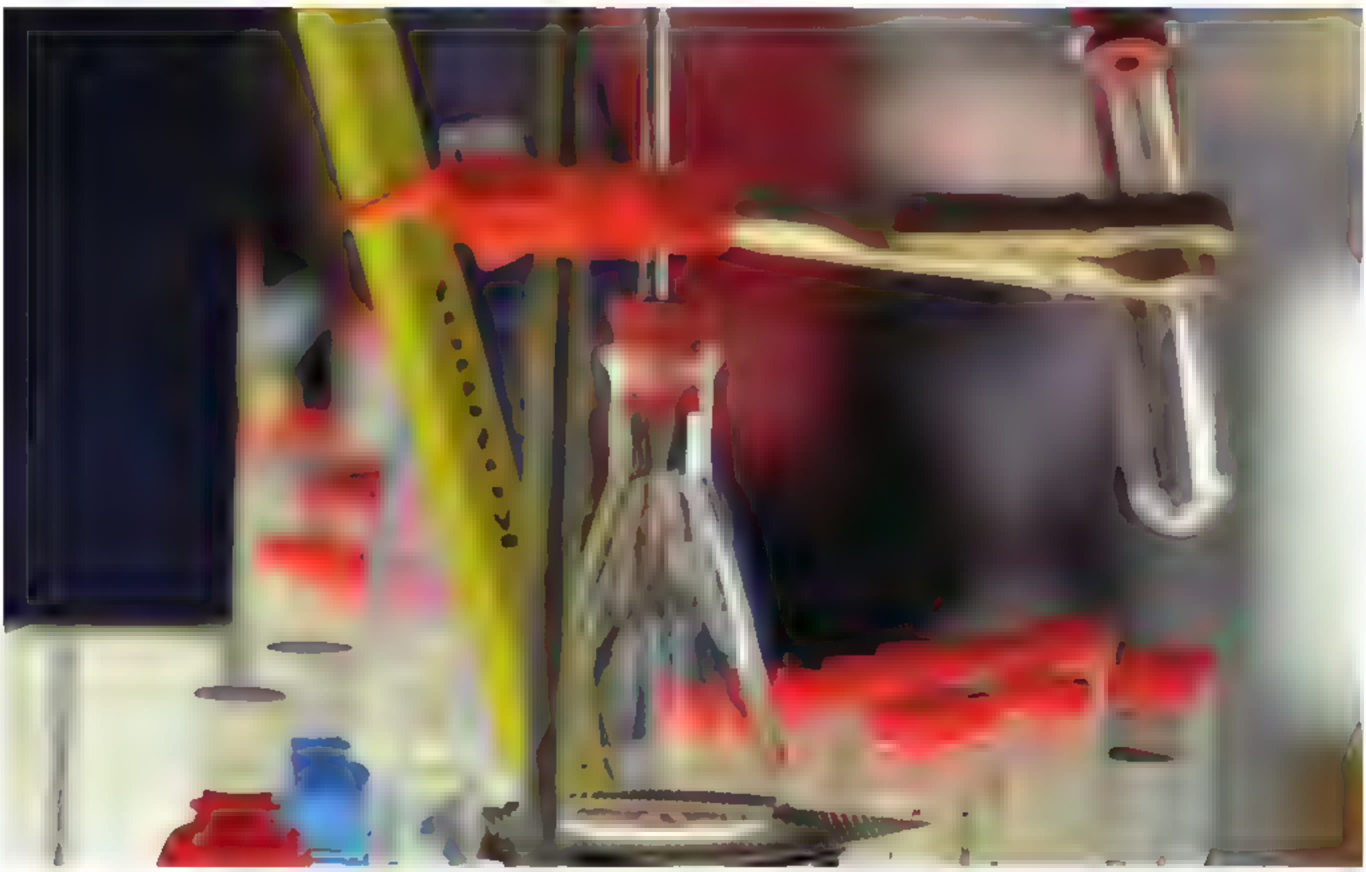


Hydrogen atom   Oxygen atom   Hydrogen atom

5) How many electrons do hydrogen and oxygen atoms share to form water molecule?

CHAPTER 02

CHEMICAL REACTIONS AND EQUATIONS



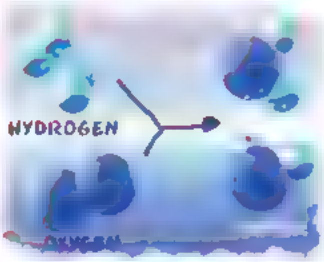
ACHIEVEMENTS

After complete studying this chapter, the student should be able to:

* conclude the concept of a chemical reaction and chemical equation.
* write and balance the chemical equation.
* expresse the interaction equation verbal and symbolic.
* know types of chemical reactions.
* understand the impact factors on the chemical reaction.
* aware the relationship between the Avogadro's number and the concept of the mole.

2-1 CHEMICAL REACTIONS

Let's start with the idea of a reaction. In chemistry, a reaction happens when two or more molecules interact and the molecules change. That's it. What molecules are they? How do they interact? What happens? The possibilities are infinite. When you are trying to understand reactions, imagine that you are working with the atoms. Imagine the building blocks are right in front of you on the table, instead of billions of reactions in your beaker. Sometimes we do this using our chemistry toys to help us visualize the movement of the atoms. There are a few key points you should know about chemical reactions:

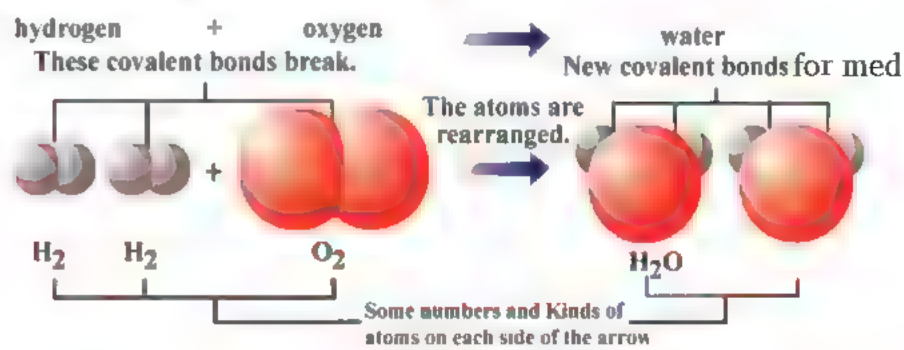


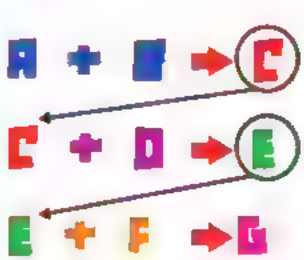
HYDROGEN AND OXYGEN MOLECULES COMBINE TO FORM WATER

1. A chemical change must occur You start with one compound and turn it into another That's an example of a chemical change A steel garbage can rusting is a chemical reaction. That rusting happens because the iron (Fe) in the metal combines with oxygen (O_2) in the atmosphere. When a refrigerator or air conditioner cools the air, there is no reaction between the air molecules. The change in temperature is a physical change. When you melt an ice cube, it is a physical change. When you put bleach in the washing machine to clean your clothes, a chemical change breaks up your stains.

2. A reaction could include ions, compounds, or molecules of a single element. We said molecules in the previous paragraph, but a reaction can happen with anything, just as long as a chemical change occurs (not a physical one). If you put pure hydrogen gas (H_2) and pure oxygen gas in a room, they can be involved in a reaction. The slow rate of reaction will have the atoms bonding to form water (H_2O) very slowly. If you were to add a spark, those gases would create a reaction that would result in a huge explosion. Chemists call that spark a catalyst.

The formation of water from Hydrogen and Oxygen





3. Single reactions often happen as part of a larger series of reactions. Take something as simple as moving your arm. The contraction of that muscle requires sugars for energy. Those sugars need to be metabolized. You'll find that proteins need to move in a certain way to make the muscle contract. A whole series (hundreds) of different reactions are needed to make that simple movement happen. In the case of your arm, some are physical changes and some are chemical. In the process of making sugars in a plant, you might have as many as a dozen chemical changes to get through the Calvin cycle which makes glucose ($C_6H_{12}O_6$) molecules.

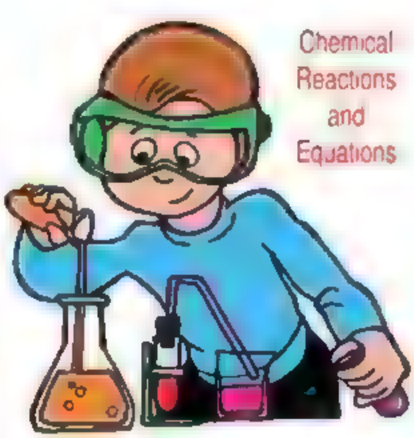
Chemical reactions are occurring inside our bodies and around us at every moment. The food we eat is involved in a large number of chemical reactions to produce energy, as well as to make tissues and other substances in our bodies.

Outside our bodies the number and types of chemical reactions are more abundant and obvious. From the burning of birthday candles on our cakes to the burning of gasoline in our car engines, combustion is a vital chemical reaction we use and see on a daily basis. The processing of materials to produce plastics is an example of chemical reactions. The number and types of chemical reactions are many, but in each case there is a common property: the production of new substances. In chemical reactions starting substances called reactants have their atoms rearranged to form products. The products contain the same number and types of atoms as the reactants but have rearranged to form new substances.

Scientists such as John Dalton (1766-1844) developed our view of chemical reactions in terms of the rearrangement of atoms. The contributions of many scientists and many years of research have further developed our understanding of chemical reactions. We now know that in chemical reactions the electrons that surround the nuclei of atoms play a key role through their ability to form chemical bonds with other atoms. These chemical bonds can be formed in a number of ways, including the sharing of electrons to form covalent bonds or the complete transfer of electrons to other atoms to form ionic bonds. An understanding of chemical bond formation is essential to understanding and predicting chemical reactions.

Energy is required to initiate all chemical reactions, though ultimately some chemical reactions release energy to the surroundings and other chemical reactions absorb energy from the surroundings. The rate at which chemical reactions occur is also a vital consideration. Chemical reactions show a great deal of variation, from the slow rusting of a car to the rapid combustion of gasoline in the engine. Scientists have studied reaction rates in detail, since controlling reaction rates in the production of materials is very important. There are many variables that can affect chemical reaction rates, and these variables include temperature, pressure, and the presence of special substances called catalysts, which accelerate the reaction rate without themselves being consumed.

2-2 CHEMICAL EQUATIONS



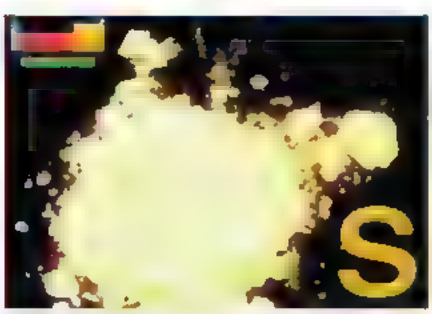
A chemical equation is a type of relation you will encounter every day in chemistry. Here's a look at what a chemical equation is and some examples of chemical equations.

A chemical equation is a written representation of the process that occurs in a chemical reaction. A chemical equation is written with the **reactants** on the left side of an **arrow** and the **products** of the chemical reaction on the right side of the equation. The head of the arrow typically points toward the right or toward the product side of the equation, although reactions may indicate equilibrium with the reaction proceeding in both directions simultaneously.

Important!!!

Coefficients are used to balance an equation. In a balanced equation, the number of each kind of atom is the same on both sides of the arrow. You can change the coefficients to balance an equation. You should never change the subscripts in the formula of a compound in order to balance the equation. This kind of reactions are called as the balanced chemical equation.

+



When Mg and S react, they form MgS.

MgS

The elements in an equation are denoted using their symbols. **Coefficients** next to the symbols indicate the stoichiometric numbers. **Subscripts** are used to indicate the number of atoms of an element present in a chemical species.

An example of a chemical equation may be seen in the combustion of methane:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Participants in the Chemical Reaction: Element Symbols

You'll need to know the symbols for the elements to understand what is taking place in a chemical reaction. In this reaction, C is carbon, H is hydrogen and O is oxygen.

Left Side of Reaction: Reactants

The reactants in this chemical reaction are methane and oxygen: CH_4 and O_2 .

Right Side of Reaction: Products

The products of this reaction are carbon dioxide and water: CO_2 and H_2O.

Direction of Reaction: Arrow

It is the convention to right the reactants on the lefthand side of the chemical equation and the products on the righthand side of the chemical equation. The arrow between the reactants and products should point from left to right.

Example 2-1

Magnesium and sulfur elements are chemically combined to form compound magnesium sulfide. Write the word equation and the formula equation for this reaction.

Answer:

Firstly, let's write the word equation. To write a word equation for any chemical reaction, we should recognize the elements and know the symbols of these elements.

magnesium + sulfur → magnesium sulfide (word equation)

$Mg + S \rightarrow MgS$ (formula equation)

Example 2-2

Magnesium and oxygen elements are chemically combined to form magnesium oxide. Write the the word equation and the formula equation for this reaction.

Answer:

Magnesium + Oxygen → Magnesium oxide (word equation)

$Mg + 1/2O_2 \rightarrow MgO$ (formula equation)

Balancing chemical equations;

A chemical equation describes what happens in a chemical reaction. The equation identifies the reactants (starting materials) and products (resulting substance). Balancing a chemical equation refers to establishing the mathematical relationship between same elements of reactants and products.

Coefficients are used to balance an equation. In a balanced equation, the number of each kind of atom is the same on both sides of the arrow. You can change the coefficients to balance an equation. You should never change the subscripts in the formula of a compound in order to balance the equation.

What coefficients must be written and where should they be placed, in order to balance the following equation:

$$Fe + O_2 \rightarrow Fe_2O_3$$

There is only 1 iron atom on the left and 2 iron atoms on the right. Then you write 2 as the coefficient of Fe. There are 2 oxygen atoms on the left and 3 oxygen atoms on the right. You may write 3/2 in front of O_2.

$$2\,Fe + 3/2\,O_2 \rightarrow Fe_2O_3$$

You can multiply both sides of the equation by 2, if you want to see the whole number coefficients.

$$4\,Fe + 3\,O_2 \rightarrow 2\,Fe_2O_3$$

This equation shows that four atoms of (4Fe) iron combine with three molecules of oxygen ($3O_2$) to form two molecules of rust ($2\,Fe_2O_3$).

Exercise 2-1

Express the following chemical reactions both in word and formula equations.

1- Methane gas burns with oxygen gas to produce carbon dioxide and water.

2- After dissociation of calcium carbonate, calcium oxide and carbon dioxide compounds are produced.

3- The reaction between nitrogen gas and hydrogen produce ammonia.

Exercise 2-2

1- Write a balanced chemical equation for each reaction.

a) water → hydrogen + oxygen

b) calcium hydroxide + hydrochloric acid → calcium chloride + water

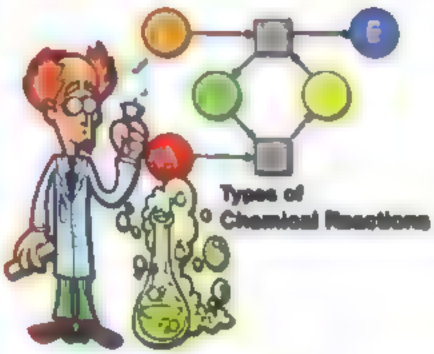
c) magnesium + sulfuric acid → magnesium sulfate + hydrogen

d) calcium carbonate → calcium oxide + carbon dioxide

2- Balance the following equations.

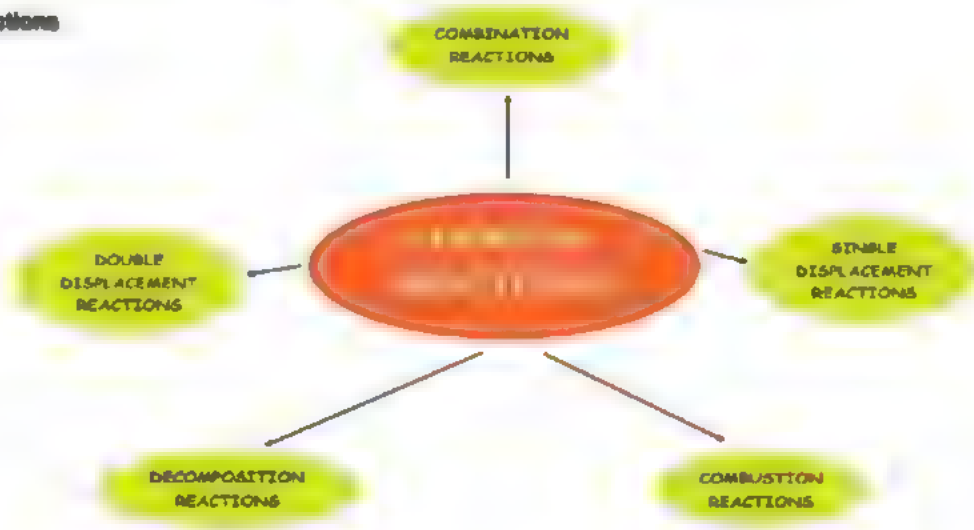
a) $KClO_3 \rightarrow KCl + O_2$

b) $Fe + H_2O \rightarrow Fe_3O_4 + H_2$



2-3 TYPES OF CHEMICAL REACTIONS

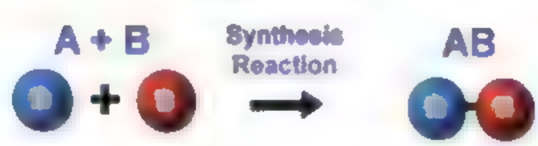
A chemical reaction is a process that is usually characterized by a chemical change in which the starting materials (reactants) are different from the products. Chemical reactions tend to involve the motion of electrons, leading to the formation and breaking of chemical bonds. There are several different types of chemical reactions and more than one way of classifying them. Here are some common reaction types.



2-3-1 Combination Reactions (Synthesis Reactions)

In a combination (or synthesis) reaction, two or more simple substances combine to form a more complex substance. These reactions are in the general form:

$$A + B \rightarrow AB$$



Two or more reactants yielding one product is another way to identify a synthesis reaction. One example of a synthesis reaction is the combination of iron and sulfur to form iron(II) sulfide:

$$Fe + S \rightarrow FeS$$

Another example is simple hydrogen gas combined with simple oxygen gas to produce a more complex substance, such as water:

$$H_2 + 1/2\ O_2 \rightarrow H_2O$$

2-3-2 Decomposition Reactions

In a decomposition reaction, a compound is broken into smaller chemical species. Therefore, a decomposition reaction is the opposite of a synthesis reaction These reactions are in the general form:

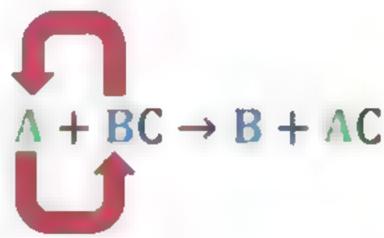
$$AB \rightarrow A + B$$

The electrolysis of water into oxygen and hydrogen gas is an example of a decomposition reaction: $2H_2O \rightarrow 2H_2\uparrow + O_2\uparrow$

$$2HgO \rightarrow 2Hg + O_2$$

2-3-3 Single Displacement Reactions

In a single replacement reaction, a single uncombined element replaces another in a compound; in other words, a substitution or single displacement reaction is characterized by one element being displaced from a compound by another element. These reactions come in the general form of:



One example of a single displacement reaction is when soduim replaces hydrogen in water to make soduim hydroxide and hydrogen gas:

$$2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow$$

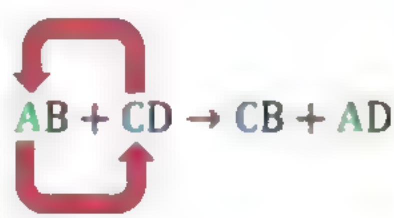
Another example of a single displacement reaction occurs when zinc combines with hydrochloric acid. The zinc replaces the hydrogen:

$$Zn + 2\ HCl \rightarrow ZnCl_2\downarrow + H_2\uparrow$$

2-3-4 Double Displacement Reactions

In a double replacement reaction, the anions and cations of two compounds switch places and form two entirely different compounds. These reactions are in the general form:

$$AB + CD \rightarrow AD + CB$$



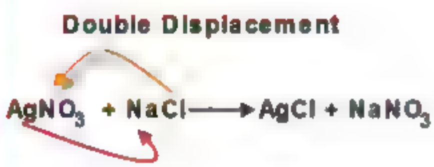
For example, when barium chloride, $BaCl_2$ and magnesium sulfate, $MgSO_4$

react, the sulfate, SO_4^{2-} anion switches places with the chloride, Cl^- anion, giving the compounds barium sulfate, $BaSO_4$ and magnesium chloride, $MgCl_2$.

$$BaCl_2 + MgSO_4 \rightarrow BaSO_4\downarrow + MgCl_2$$

Another example of a double displacement reaction is the reaction of lead(II) nitrate, $Pb(NO_3)_2$ with potassium iodide, KI to form lead(II) iodide, PbI_2 and potassium nitrate, KNO_3:

$$Pb(NO_3)_2 + 2\,KI \rightarrow PbI_2\downarrow + 2\,KNO_3$$

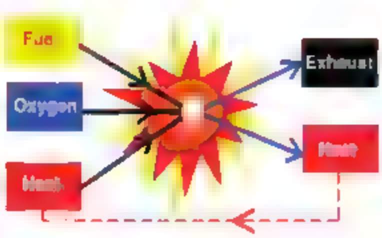


One more example of a double displacement reaction occurs between sodium chloride, NaCl and silver nitrate, $AgNO_3$ to form sodium nitrate, $NaNO_3$ and silver chloride, AgCl.

$$NaCl + AgNO_3 \rightarrow NaNO_3\downarrow + AgCl$$

2-3-5 Combustion Reactions

A combustion reaction is a major class of chemical reactions. Combustion usually occurs when a hydrocarbon reacts with water to produce carbon dioxide and water. In the more general sense, combustion involves a reaction between any combustible material and an oxidizer to form an oxidized product. Combustion is an exothermic reaction, so it releases heat, but sometimes the reaction proceeds so slowly that a temperature change is not noticeable. Good signs that you are dealing with a combustion reaction include the presence of oxygen as a reactant and carbon dioxide, water and heat as products.

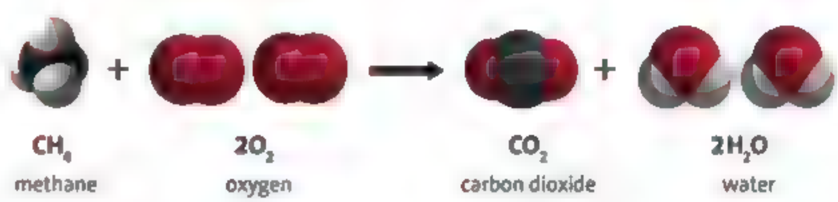


General Form of a Combustion Reaction

Hydrocarbon + Oxygen → Carbon dioxide + Water

Examples of Combustion Reactions

Combustion of methane



Burning of naphthalene

$$C_{10}H_8 + 12O_2 \rightarrow 10CO_2 + 4H_2O$$

Combustion of ethane

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

Exercise 2-3

Determine the type of each of the following reactions :-

$H_2 + I_2 \rightarrow 2HI$

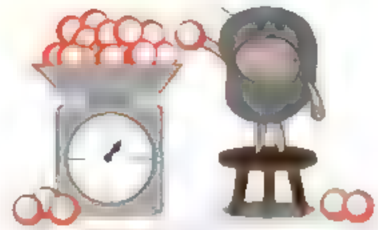
$2HBr \rightarrow H_2 + Br_2$

$Cl_2 + KBr \rightarrow 2KCl + Br_2$

$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$

2-4 AVOGADRO'S NUMBER AND MOLE CONCEPT

Avogadro's number and the mole are very important to the understanding of atomic structure. The chemical changes we observe always involve discrete numbers of atoms that rearrange themselves into new configurations. These numbers are huge— far too large in magnitude for us to count or even visualize, but they are still numbers, and we need to have a way to deal with them. We also need a bridge between these numbers, which we are unable to measure directly, and the weights of substances, which we do measure and observe. The mole concept provides this bridge, and is central to all of quantitative chemistry.


6.02×10^{23} atoms
in 12 grams of carbon

The size of molecule or atom is so small that it is physically difficult if not impossible to directly count out molecules. This problem is solved using a common trick. Atoms and molecules are counted indirectly by weighing. Here is a practical example of counting by weighing. .

You need to estimate the number of nails in a box. You weigh an empty box, 213 g. The weight of the box plus nails is 1340 g. The weight of one nail is 0.45 g. I hope you are not going to tear open the package and count the nails. We agree that mass of nails = 1340 g - 213 g = 1227 g Number of nails = (1227 grams nails)(1 nail/ 0.450 grams) = 2726.6 nails = 2730 nails. You can count the nails by weighing them.

Avogadro's number is an accident of nature. It is the number of particles that delivers a mole of a substance.
Avogadro's number = 6.02×10^{23}.
The reason why the value is an accident of nature is that the mole is tied to the gram mass unit.

The gram is a convenient mass unit because it matches human sizes. If we were a thousand times greater in size we would find it handy to use kilogram amounts. This means the kilogram mole would be convenient. The number of particles handled in a kilogram mole is 1000 times greater. The kilo Avogadro number for the count of particles in a kilomole is 6.02×10^{26}.

If humans were tiny creatures only 1/1000 our present size, milligrams would be more convenient. This means the milligram mole would be more useful. The number of particles handled in a milligram mole (millimole) would be 1/1000 times smaller. The milli Avogadro number for the count of particles in a millimole is 6.02×10^{20}.

1 mole of element contains 6.02×10^{23} atoms.
1 mole of compound contains 6.02×10^{23} molecules.
1 mole of hydrogen ion contains 6.02×10^{23} ions.
1 mole of electron is equal to 6.02×10^{23} electrons.

To determine the mass a single tiny atom, equal-arm balance cannot be used to measure it. Because atoms and molecules are so tiny particles. To get it closer to human mind, Avogadro' s Number which is 6.02×10^{23}, mass of that much of atoms and molecules can be found. For example: 6.02×10^{23} hydrogen atoms weigh only 1 g. Think about the mass a single hydrogen atom how tiny it is. So, mole concept is something like a bridge used to determine the quantity of elementary entities (atoms, molecules, ions, electrons) by the help of Avogadro's Number.

CHAPTER QUESTIONS 02

2-1 Define the following terms.
Chemical equation, chemical reaction, mole, reactant, product

2-2 What are the benefits of a chemical equation?

2-3 Show the following reactions with a balanced formula equation.

1. Silver + Chlorine gas → Silver chloride
2. Copper + Oxygen gas → Copper (II) oxide
3. Zinc + Chlorine gas → Zinc chloride
4. Iron + Oxygen → Iron (II) oxide
5. Sodium + Chlorine gas → Sodium chloride

2-4 Balance the following reactions.

1. $Mg + O_2 \rightarrow MgO$
2. $Mg + N_2 \rightarrow Mg_3N_2$
3. $N_2 + O_2 \rightarrow NO$
4. $CO + O_2 \rightarrow CO_2$
5. $Hg + O_2 \rightarrow HgO$

2-5 Correct if there is something wrong in balancing of the following equations.

1. $Al + O_2 \rightarrow Al_2O_3$
2. $CH_4 + O_2 \rightarrow CO_2 + H_2O$
3. $2K + Br_2 \rightarrow 2KBr$

2-6 Write the names of types of the chemical reactions and give an example for each of them.

2-7 At the high temperature, potassium chlorate compound, $KClO_3$ decomposes into potassium chloride, KCl and oxygen gas, O_2 as shown in the following reaction: $2KClO_3 \rightarrow 2KCl + 3O_2$
Write what you deduce from this reaction.

2-8 Complete the following reactions and then determine the type of each reaction.

1. $Br_2 + KI \rightarrow$
2. $Zn + HCl \rightarrow$
3. $Ca + Cl_2 \rightarrow$
4. $NaClO_3 \rightarrow$
5. $C_7H_{14} + O_2 \rightarrow$
6. $CuCl_2 + Na_2S \rightarrow$

2-9 Write the balanced chemical reaction between the givens below.

1. Metal and oxygen
2. Nonmetal and oxygen
3. Metal and nonmetal

2-10 Complete the following reactions and then balance each of them.

1. $Hg + HCl \rightarrow$
2. $Na + H_2O \rightarrow$
3. $Fe + CuSO_4 \rightarrow$

2-11 Complete the following chemical reactions and then balance them.

1. $Li + ... \rightarrow Li_2O$ (Combination Reaction)
2. $Na + H_2O \rightarrow ....$ (Single Replacement Reaction)
3. $HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + ...$ (Double Displacement Reaction)

2-12 Classify the following reactions.

1. $N_2 + 3H_2 \rightarrow 2NH_3$
2. $2Li + 2H_2O \rightarrow 2LiOH + H_2$
3. $2NaNO_3 \rightarrow 2NaNO_2 + O_2$
4. $2C_6H_{14} + 19O_2 \rightarrow 12CO_2 + 14H_2O$
5. $NH_4Cl \rightarrow NH_3 + HCl$
6. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

2-13 Balance the following reactions and then write the type of each reaction.

1. $H_2 + Cl_2 \rightarrow HCl$
2. $Mg + O_2 \rightarrow MgO$
3. $BaO + H_2O \rightarrow Ba(OH)_2$
4. $H_2CO_3 \rightarrow CO_2 + H_2O$
5. $H_2O \rightarrow H_2 + O_2$
6. $Ca + H_2O \rightarrow Ca(OH)_2 + H_2$
7. $KI + Br_2 \rightarrow KBr + I_2$

CHAPTER 03

HYDROGEN

ACHIEVEMENTS

After complete studying this chapter, the student should be able to:-

* recognize hydrogen and its symbol and chemical formula.
* draw the electronic structure of the hydrogen atom.
* know how the hydrogen discover and being in nature.
* prepare hydrogen in different methods
* show the importance and uses of hydrogen gas.
* know the properties of hydrogen and chemical interactions.
* understand the reductent reduction.

3-1 INTRODUCTION

Hydrogen is a colorless, odorless and tasteless gas. Since hydrogen gas is lighter (d = 0.0899 g/L at STP) than other gas molecules,

Although hydrogen is insoluble or only slightly soluble in water and other solvents,

Hydrogen forms ionic hydrides with active metals, such as potassium hydride, KH. It forms covalent compounds with nonmetals, for example HF, HCl, H_2O, etc. Electronegativity of hydrogen is higher than that of metals, but less than that of nonmetals.

The first men riding in a hydrogen balloon. (in France, 1783)

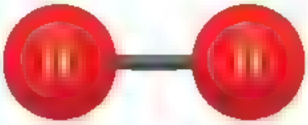
3-2 PLACEMENT IN THE PERIODIC TABLE

Although hydrogen is placed in the periodic table at the head of group 1A, in fact it does not show alkali metal properties. However, it is placed in group 1A because of its one valence electron.

For example, it forms covalent bonds, it is found in the form of diatomic molecule, H_2, in the gaseous state.

Some properties of hydrogen

Name	Hydrogen
Symbol	H
Atomic number	1
Atomic mass number	1
Common oxidation numbers	-1, +1
Color	colorless
Physical state at 25°C	gas
Origin and meaning of name	*Hydro and genes* - water and generator



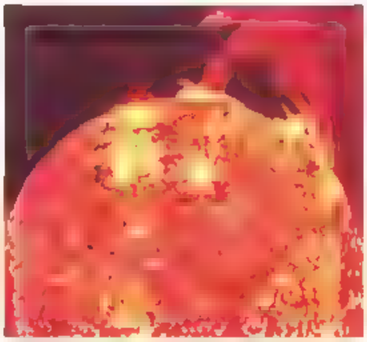
Diatomic hydrogen molecule

H - H

3-3 OCCURRENCE

Hydrogen occurs in the form of free diatomic molecules and its compounds. Free hydrogen occurs in nature only in negligible amounts, for example, in volcanic gases.

Hydrogen gas easily escapes from earth's gravitation to enter space beyond the atmosphere. It makes up about 0.15% by mass and 15.5% by the number of atoms, of the earth's crust and atmosphere. The most important compound of hydrogen is water(H_2O). It is also found as a component of organic substances such as hydrocarbons, oil, coal, and natural gas. Clays and certain hydrates are common inorganic compounds which contain hydrogen.



Hydrogen comprises the greatest part of the sun by mass. In each second, 550 millions tons of hydrogen is consumed to give us heat and light.

3-5 PREPARATION

3-5-1 In the Laboratory

Reaction of calcium hydride CaH_2 with water gives hydrogen gas.

A. Hydrogen is produced by the reactions of metals with acids, active metals with water and amphoteric metals with bases shown in the following figures.

The reaction of zinc with hydrochloric acid.

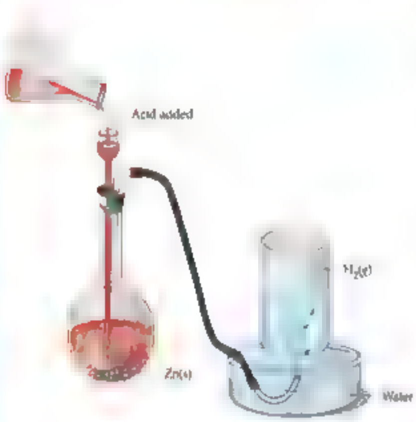
$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}\uparrow$$

B. The reactions of alkali metal hydrides and calcium hydride with water produce H_2 gas.

a. $CaH_{2(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + 2H_{2(g)}\uparrow$

The reaction of metals like Na K with water

produce hydrogen gas H_2



b. The reaction of sodium with water.

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$$

C. Electrolysis of water and solutions of some acids, bases and salts release H_2 gas as well.

$$2HCl + H_2O \xrightarrow{\text{electrolysis}} H_2 + Cl_2 + H_2O$$

$$2NaOH + 2H_2O \xrightarrow{\text{electrolysis}} 2H_2 + O_2 + 2NaOH$$

$$2NaCl + 2H_2O \xrightarrow{\text{electrolysis}} H_2 + Cl_2 + 2NaOH$$

The electrolysis of water produces hydrogen and oxygen gases.

Although hydrogen produced by the electrolysis of water is rather pure,it is expensive, since electrolysis requires extreme amount of electricity. This method is not used in industry.

$$2H_2O_{(l)} + 112806KJ \rightarrow 2H_{2(g)} + O_{2(g)}$$

3-5-2 In Industry

A. The CO_2 produced in this process is liquified under high pressure. Thus, rather pure H_2 gas is obtained. By using coal, this process is accomplished in one step as in the reaction below.

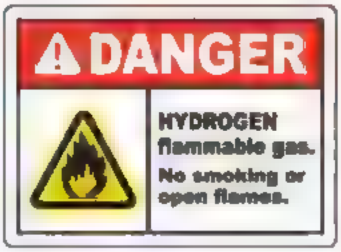
$$C_{(s)} + 2H_2O_{(g)} \rightarrow CO_{2(g)} + 2H_{2(g)}$$

B. Preparation of H_2 from hydrocarbons

Hydrocarbons, extracted from oil and natural gas, contain carbon and hydrogen. For example by decomposing hydrocarbons with the help of heat without oxygen, hydrogen gas is produced heat.

$$CH_4 \rightarrow C + 2H_2$$

3-6 CHEMICAL PROPERTIES



1. Hydrogen is used especially to produce ammonia in industry. Nitrogen and hydrogen are reacted under high pressure and temperature to produce ammonia, according to the reaction below.

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

2. Oils have low melting points because of the double bonds between carbon atoms in oil molecules. Hydrogen is used to saturate oils. By saturating these double bonds with hydrogen, fats, such as margarines, are produced.

3. H_2 gas is a good reducing agent. Because of this property it is widely used in the production of metals from their oxides. For example,metallic iron, copper and tungsten are produced from their oxides in this way.

$$CuO + H_2 \rightarrow Cu + H_2O$$

Blue Flame of hydrogen

4. Methanol, CH_3OH, is produced in industry as a result of the reaction between hydrogen and carbon monoxide (water gas). Water gas, a mixture of hydrogen and carbon monoxide, is an important industrial fuel.

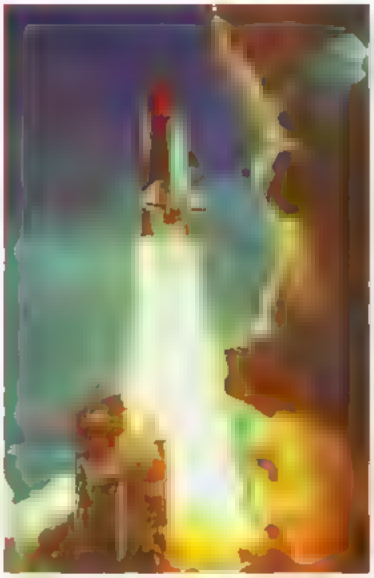
$$CO + 2H_2 \rightarrow CH_3OH$$

5. Since the reaction of hydrogen with oxygen is an exothermic process, hydrogen is now considered a potential fuel. Water products do not damage the environment, so hydrogen may be an alternative energy source in the future.

$$2H_2 + O_2 \rightarrow 2H_2O + 485\ kJ$$

Hydrogen reacts with oxygen in a normal reaction rate by giving a blue flame. If a glass plate is exposed to this flame, after a period of time water vapor appears on the glass surface. That is, water vapor is produced by this reaction.

reading — Hydrogen as a Fuel



Today more than 70% of all energy demand is supplied by fossil fuels. Fossil fuels, such as petroleum, natural gas and coal, are non-renewable and their by-products pollute the environment.

The fossil fuels that supply most of today's world energy demand are rapidly being exhausted. In addition, their combustion products are causing global problems such as the greenhouse effect, ozone layer depletion, acid rain and pollution, which pose great danger to our environment and, eventually, to all life on our planet.

Realizing these drawbacks, scientists have been seeking alternative energy sources, and hydrogen is the most outstanding one.

Hydrogen is a very efficient and clean fuel whose only by product is water.

Hydrogen can be used in almost every application in which fossil fuels are being used today. Hydrogen can be used as a fuel in furnaces, internal combustion engines, and turbine and jet engines even more efficiently than fossil fuels. Automobiles, buses, trains, ships, submarines, planes and rockets can run on hydrogen.

Energy from hydrogen can also be converted to electricity by special devices called fuel cells.

Liquid hydrogen has been used since the 1970s to propel the space shuttles and other rockets into orbit. Hydrogen fuel cells power the shuttle's electrical system, producing a clean by-product, pure water, which the crew drinks.

Although hydrogen seems to be one of the most advantageous alternative energy sources, there are still some problems to overcome, such as storage, distribution and cost.

Storage: Since hydrogen is so light, it is difficult to store a lot of it in a small tank.

Distribution: There is not a widespread distribution channel for getting hydrogen to the masses. A new infrastructure will need to be put in place.

Cost: Hydrogen is much more expensive than gasoline.

Hopefully, in a few decades, scientists will overcome these problems and we will begin to live with a much cleaner energy source, hydrogen.

CHAPTER QUESTIONS 03

3-1 Discuss the position of hydrogen in the periodic table.

3-2 How is hydrogen prepared in the laboratory and in industry?

3-3 Label the following statements as true (T) or false (F).

.... a. Hydrogen is a mono-atomic colorless gas at room temperature.

.... b. Hydrogen resembles alkali metals

..... c. Hydrogen is a good oxidizing agent.

..... d. Hydrogenation is a process of hydrogen removal.

3-4 Complete and balance the following equations:

a. $CO + H_2 \rightarrow$
b. $C + H_2O \rightarrow$
c. $Ca + H_2 \rightarrow$
d. $C_2H_6 + H_2O \rightarrow$

3-5 Write 5 reactions between the following substances.

1. HCl 2. H_2 3. CuO 4. Zn 5. O_2

3-6 Hydrogen can act both as an oxidizing agent and a reducing agent in chemical reactions. Give one example of each and determine the oxidation number of hydrogen.

3-7 Hydrogen has been proposed as a replacement for hydrocarbons as a fuel. Discuss the advantages and disadvantages of this proposal. Some topics you might consider are: source, renewability, safety, cost, storage and the environment.

3-8 Choose the correct answer for the following questions.

1. Which one is not correct for hydrogen?

A) Its symbol is H.
B) Its atomic number is 1.
C) It has no neutron.
D) Its physical state is solid .

2. Which of the following is not true for hydrogen?

A) It occurs in the form of free diatomic molecules.
B) It occurs in the form of compounds.
C) It is the most abundant element in the universe.
D) It is found as a component of hydrocarbons.
E) It is the most abundant element in the earth's crust.

3. Which substance does not contain hydrogen?

A) Water B) Ammonia
C) Alcohols D) Acids E) Table salt

4. Which of the following is not used in the industry preparation of hydrogen?

A) Metal - acid reactions
B) Metal - water reactions
C) Electrolysis of water
D) Decomposition of hydrocarbons

5. Which of the following reactions does not produce hydrogen gas?

A) $Zn + HCl \rightarrow$
B) $Zn + NaOH \rightarrow$
C) $2Na + 2H_2O \rightarrow$
D) $CH_4 \rightarrow$
E) $H_2O \xrightarrow{\text{electrolysis}}$

6. In which of the given compounds does hydrogen have a different oxidation state?

A) HCl
B) HNO_3
C) CH_3COOH
D) $NaOH$
E) KH

7. Which one of the following is not a use of hydrogen?

A) In the synthesis of methanol
B) In the reduction of metals
C) In the synthesis of NH_3
D) In preparing margarines
E) In preparing pesticides

8. Which of the following is/are exactly correct about all neutral hydrogen atoms?

I. All possess 1 proton.
II. All possess 1 electron.
III. All have a mass of 1 amu.

A) I only
B) I and II
C) I and III
D) II and III
E) I, II and III

CHAPTER 04

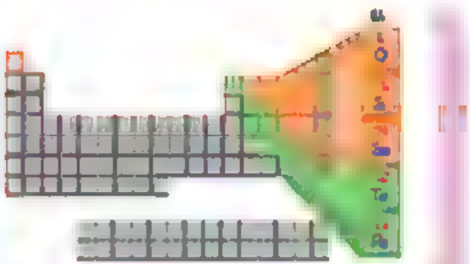
OXYGEN

ACHIEVEMENTS

After complete the study of this chapter, the student should be able to:

* recognize the oxygen symbol and chemical formula.
* write the electronic canfiguration for oxygen atom.
* know how oxygen gas was discovered, and being in nature.
* show the importance of oxygen gas of living.
* learn how to prepare oxygen in laboratory and industrial .
* recognize the physical and chemical properties of oxygen
* know how oxides are composed and their types
* recognize the ozone gas and what are the chemical formula.
* understand the importance of the ozone layer in the atmosphere and what substances that deplete this layer are.

4-1 INTRODUCTION



Group 6A is known as the oxygen group, oxygen family.

Symbol : O

Molecular formula : O_2

Atomic number : 8

Mass number : 16

Symbol of energy level	Energy Level (n)	Number of electrons
K	1	2
L	2	6

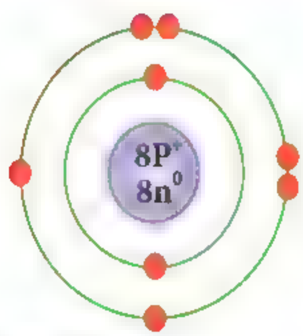


Figure 4-1
Electron configuration of oxygen atom

Oxygen is the second most electronegative non-metal elements after fluorine . That's why oxygen is the best oxidizing agent in the group.

oxygen has six electrons in his valence shell. It try to gain 2 electrons or share electrons to complete the number of electrons in the valence shell. Accordingly, it tend to have –2 oxidation number.

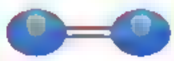
Oxygen is a gas. The bonding capacity of oxygen is limited to two

Oxygen forms ionic compounds with all metals

4-2 OXYGEN

Oxygen was discovered by Priestley in 1774. The name oxygen, which means acid-producer, comes from Greek.

Oxygen is the first member of group 6A with electron arrangement 2,6 . It is a nonmetal and the most active element of the group. It has two allotropes: oxygen gas, O_2, and ozone, O_3.



diatomic structure of oxygen

4-2-1 Oxygen gas

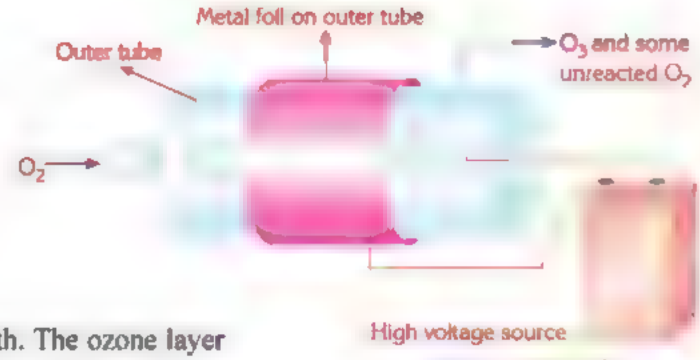
Oxygen is a colorless, tasteless, odorless gas, and it exists in a diatomic structure. Oxygen gas O_2 is more stable than ozone. O_3 The density of oxygen is greater than air. It dissolves slightly in water.

4-2-2 Ozone

Ozone (O_3) is a light blue colored gas with a sharp, pleasant odor. It may be liquefied at –112°C and may be solidified at –193°C.

Ozone is slightly soluble in water. Ozone can be prepared by passing pure oxygen gas through an electrical discharge (Look at the Figure).

$$3O_{2(g)} \rightarrow 2O_{3(g)}$$



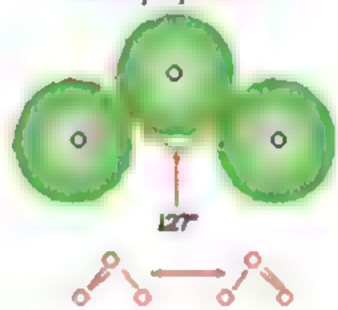
ozone preperation

The electrical energy breaks the bonds in some O_2 molecules to give oxygen atoms, which react with other O_2 molecules to form O_3.

$$O_2 \rightarrow 2O \qquad O_2 + O \rightarrow O_3$$

Ozone exists naturally in the upper atmosphere of the earth. The ozone layer is especially important because it absorbs ultraviolet light, acting as a screen to block this radiation, which can cause skin cancer. When an ozone molecule absorbs this energy, it splits into an oxygen molecule and an oxygen atom.

$$O_3 \xrightarrow{\text{energy}} O_2 + O$$



two forms of ozone resonance

The characteristic smell of ozone can often be detected near high voltage electrical apparatus, such as some early model photocopiers.

4-3 OCCURRENCE

Oxygen is the most abundant element on the earth. It occurs in nature in both the free and combined states. Free oxygen constitutes about 21% by volume of atmospheric air, and about 33% by volume of dissolved air. In compounds, oxygen accounts for about 50% of the mass of the earth's crust, oceans and air. Oxygen is present as oxides of both metals and non-metals, which make up the rocks and clays. Water, one of the most abundant compounds on the earth, contains 88.9% oxygen by mass.

Oxygen is present in water molecules, and water is essential to all life. Oxygen is present in many organic compounds. Most living organisms use oxygen for respiration. Oxygen makes up1/ 4 of the atoms in living organisms.

4-3-1 Preparation

Preparation of oxygen in the laboratory and in industry are mentioned below.

a. In the Laboratory

Generally the thermal decomposition method is used to prepare oxygen gas in laboratories.

a) Heating of metal oxides with low activity such as Ag_2O and HgO.

$$2HgO_{(s)} \xrightarrow{\text{heat}} 2Hg_{(l)} + O_{2(g)}$$

$$Ag_2O_{(s)} \xrightarrow{\text{heat}} 2Ag + 1/2O_{2(g)}$$

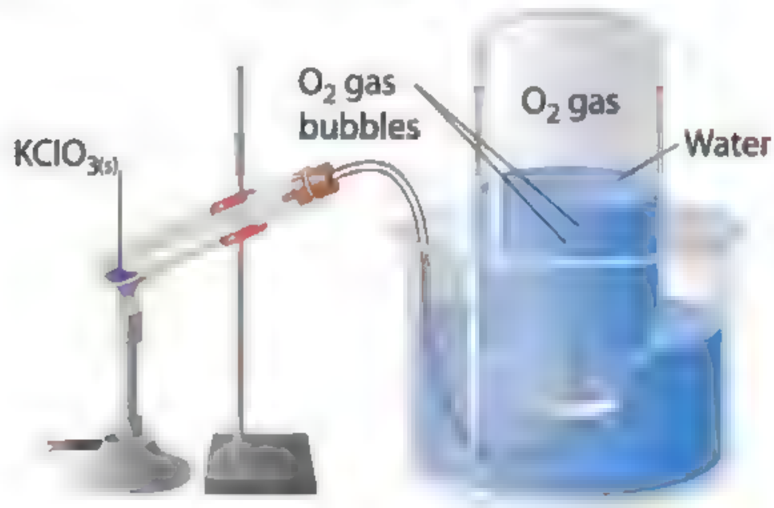
b) Heating of peroxides, such as H_2O_2:

$$2H_2O_{2(l)} \xrightarrow{MnO_2} 2H_2O_{(l)} + O_{2(g)}$$

Electrolysis of Water
In electrolysis of water, hydrogen (at right) and oxygen (at left) gases are produced in 2:1 ratio.

c) Heating of chlorate (ClO_3^-) compounds:

$$2KClO_{3(s)} \xrightarrow{heat} 2KCl_{(s)} + 3O_{2(g)}$$



d) Heating of permanganate (MnO_4^-) compounds:

$$2KMnO_{4(s)} \xrightarrow{heat} K_2MnO_{4(s)} + MnO_{2(s)} + O_{2(g)}$$

e) Electrolysis of water:

$$2H_2O_{(l)} \xrightarrow{electrolysis} O_{2(g)} + 2H_{2(g)}$$

This method is more expensive than the others.

b. In Industry

The preparation of oxygen in industry involves two main steps: the liquefaction of air, and the fractional distillation of the liquid air.

1. Liquefaction of air

Air, in the gaseous form, is first passed through caustic soda to remove any CO_2 present. It is then compressed to a pressure of about 200 atm., cooled, and allowed to escape rapidly through a very small hole. The sudden expansion of the air into a region of lower pressure causes it to cool. It is cooled until it becomes a liquid at –200°C.

2. Fractional distillation of liquid air

The liquid air is then led to a fractionating column. During distillation, nitrogen gas, with the lower boiling point of –196°C, is evolved first, leaving behind a liquid very rich in oxygen. Further heating turns the liquid oxygen into a gas at –183°C. The oxygen is dried, compressed and stored in steel cylinders under a pressure of 100 atm.

4-4 CHEMICAL PROPERTIES

Even though oxygen is the second most active nonmetal, the reactions of oxygen are slow because of the strong double bond between oxygen atoms. Generally oxygen takes –2 charge in its compounds, except OF_2. Oxygen has only +2 charge in OF_2. Oxygen combines with all elements (except the noble gases, some halogens and some unreactive metals) to form oxides.

4-4-1 Reactions

1. Reactions with metals;

a) Oxygen reacts with alkali metals to form oxides, peroxides (O_2^{2-}) or superoxides (O_2^-).

oxide peroxide superoxide

$$2Na_{(s)} + O_{2(g)} \rightarrow Na_2O_{2(s)} \text{ sodium peroxide}$$

b) Oxygen gas gives thermal reactions with other metals to form basic oxides.

$$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)} + \text{heat}$$
$$4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)} + \text{heat}$$

2. In general, all nonmetals react with oxygen gas.

a) Depending on the kind of nonmetal and amount of oxygen, different types of oxides may be formed. (Acidic oxides)

$$C_{(s)} + O_{2(g)} \xrightarrow{\Delta} CO_{2(g)}\uparrow$$
$$S_{(s)} + O_{2(g)} \xrightarrow{\Delta} SO_{2(g)}\uparrow$$
$$2S_{(s)} + 3O_{2(g)} \xrightarrow{\Delta} 2SO_{3(g)}\uparrow$$

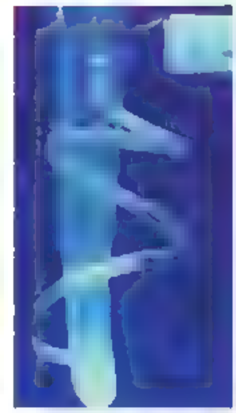
b) Reaction with nitrogen is possible at high temperature.

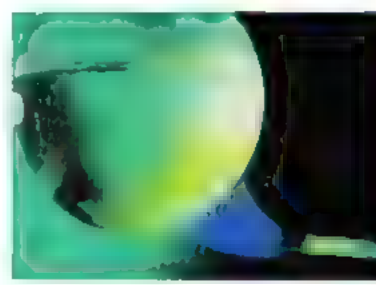
$$N_{2(g)} + O_{2(g)} \longrightarrow 2NO_{(g)}$$

3. When oxygen reacts with some compounds, the oxides of each element form.

$$2H_2S_{(g)} + 3O_{2(g)} \rightarrow 2H_2O_{(g)} + 2SO_{2(g)}$$

Oxygen is used in the burning of acetylene gas to produce a (oxy-acetylene) flame with a temperature of over 2000°C. It is used to cut through metals like steel.





Reaction of oxygen.
a: Magnesium burns with a bright flame. b: H_2S burns with a blue flame in air

CHAPTER QUESTIONS 04

4-1 What does oxygen mean in Greek language?

4-2 Write the abundance of oxygen in the earth's crust and in the atmosphere (by mass and by volume).

4-3 Write the physical properties of oxygen.

4-4 Write the preparation reactions of oxygen in the laboratory.

4-5 Write the chemical properties of oxygen and an equation corresponding to each property.

4-6 What are the main usage area of oxygen?

4-7 Air is a mixture of some gases. How would you separate oxygen from this mixture?

4-8 Complete and balance the following reactions.

a. $Mg + O_2 \rightarrow$
b. $Na + O_2 \rightarrow$
c. $C + O_2 \rightarrow$
d. $S + O_2 \rightarrow$

4-9 In laboratory, oxygen gas may be prepared by decomposition of potassium chlorate into potassium chloride and oxygen gas.
Write the balanced equation of this reaction.

4-10 Choose the correct answer for the following questions.

1. I. Ozone is an allotrope of oxygen.
II. Oxygen is lighter than air.
III. Oxygen was discovered in 1774.

Which one(s) of the above statements is/are correct for oxygen?

A) I only **B)** I and III
C) III **D)** I, II
E) I, II, III

2. Which one of the following statements is not correct for oxygen?

A) Oxygen forms ozone.
B) Oxygen is used in metallurgy.
C) Oxygen is used in diving.
D) Oxygen is needed for combustion.
E) Oxygen is a flammable gas.

3. Which one is wrong for combustion reactions?

A) Oxygen is needed. **B)** Heat is needed.
C) Light is given off. **D)** They are exothermic.
E) Water is used.

4. Which one of the following is not a method of preparation for oxygen?

A) $2HgO_{(s)} \xrightarrow{heat} 2Hg_{(s)} + O_{2(g)}$

B) $2H_2O_{2(l)} \xrightarrow{MnO_2} 2H_2O + O_2$

C) $2H_2O_{(l)} \xrightarrow{electrolysis} 2H_{2(g)} + O_{2(g)}$

D) $2KClO_{3(s)} \xrightarrow{heat} 2KCl + 3O_{2(g)}$

E) $2Ag_2O_{(s)} \xrightarrow{light} 4Ag_{(s)} + O_2$

5. Which one of the following reactions of oxygen does not occur?

A) $S + O_2 \rightarrow SO_2$

B) $Ag_2O_{(s)} \xrightarrow{heat} 2Ag + O_2\uparrow_{(g)}$

C) $2KClO_{3(s)} \xrightarrow{heat} 2KCl + 3O_{2(g)}$

D) $4Al + 3O_2 \rightarrow 2Al_2O_3$

E) $Au + 3O_2 \rightarrow 2Au_2O_3$

CHAPTER 05

WATER

ACHIEVEMENTS

After complete studying this chapter, the student should be able to:

* know that water is the basis of life on earth.
* describe the molecular structure of water.
* describe the hydrogen bonding which formed between water molecules.
* distinguish between physical and chemical properties of water.
* recognize the three state of water.
* know soft water hardness and how to get rid of brackish.
* know the ability of water as solvent to dissolve some different materials like salts or organic material

5-1 WATER , H_2O

Water is the most common and essential oxide found in nature. The compound water is the only substance naturally present on the earth in all three states: solid (near the north and south poles and in glaciers), liquid and gas (water vapor in the atmosphere).

A water molecule, red balls represent hydrogen atoms and blue ball represents oxygen atom.

5-2 OCCURRENCE

About 75% of the earth's surface is covered with water in which many other compounds (such as salt) are dissolved. Oceans, more than 97% of the water, help in the heat balance of the world.

Water is essential for all living organisms. It makes up 60% of trees, 70% of the body of an elephant and about 95% of a tomato. Our own body contains more water than any other substance: about 70% of our body is made up of water. The water we lose when we breathe out, sweat and urinate must be replaced. Water is needed to dissolve chemicals in our cells and to carry chemicals around our body. Water takes part in some metabolic reactions, and our blood is about 90% water.

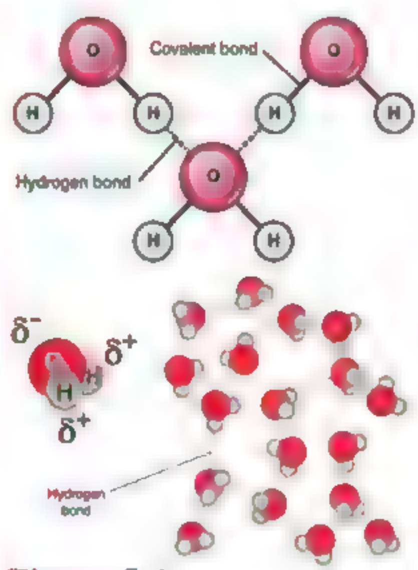
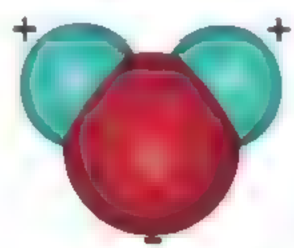


Figure 5-1
Hydrogen bond between water molecules

5-3 HYDROGEN BONDING IN WATER

As mentioned in the chapter 1, oxygen and hydrogen atoms come together and form covalent bond between them to form water molecule. Water gains physical and chemical properties from its molecules. Thus water possesses molecules which form poles like magnets. Two hydrogen atoms in water molecule form positive pole (anode) and oxygen atom forms negative pole (cathode).



Because of these two elements forming water, the water molecules attract each other and form a molecule sequencing which is shown in figure 5-1. This attraction force which occurs between water molecules is called as hydrogen bonding.

5-4 PREPARATION

Water can be prepared by the following methods.

1. Direct union of hydrogen and oxygen: Water is formed when hydrogen burns in air. This reaction is highly exothermic.

$$2H_2 + O_2 \rightarrow 2H_2O + heat$$

2. Decomposition of certain substances: Some oxygen-containing organic compounds, such as simple sugar, $C_6H_{12}O_6$, give water when they are thermally decomposed.

$$C_6H_{12}O_6 \xrightarrow{heat} 6C + 6H_2O$$

Figure 5-2
suger thermal decomposed

3. Neutralization reactions: When acids and bases react, they give salt and water as products.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

The exceptional base that doesn't release water from its neutralization reaction is ammonia, NH_3

$$NH_3 + HCl \rightarrow NH_4Cl$$

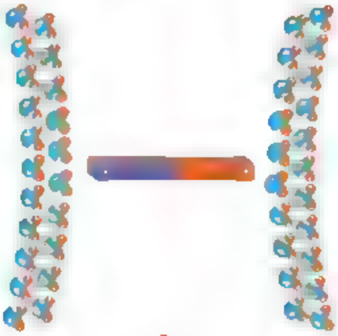
4. Reduction: When hydrogen is used as a reducing agent for metal oxides, the products are elemental metal and water.

$$CuO + H_2 \rightarrow Cu + H_2O$$

5-5 PHYSICAL PROPERTIES

Pure water is colorless and tasteless. It boils at 100°C and freezes at 0°C under 1 atmosphere pressure (at sea level). Its density is highest at 4°C: 1g/cm³. So its density decreases and volume increases when it freezes. Water is the only substance whose density is lower when it freezes. This property of water makes life possible in seas and lakes in winter.

a



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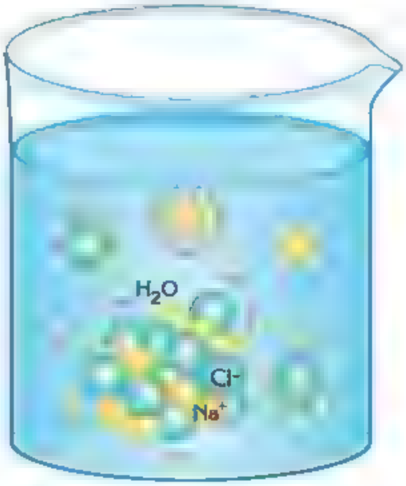


c

The water molecule is made up of two atoms of hydrogen and one atom of oxygen. Two pairs of non-bonding electrons in oxygen cause a charge imbalance in water molecules and makes them polar (Figure a-b). Therefore water can dissolve polar substances. Due to its high dissolving capacity, it is often called the universal solvent (Figure c).

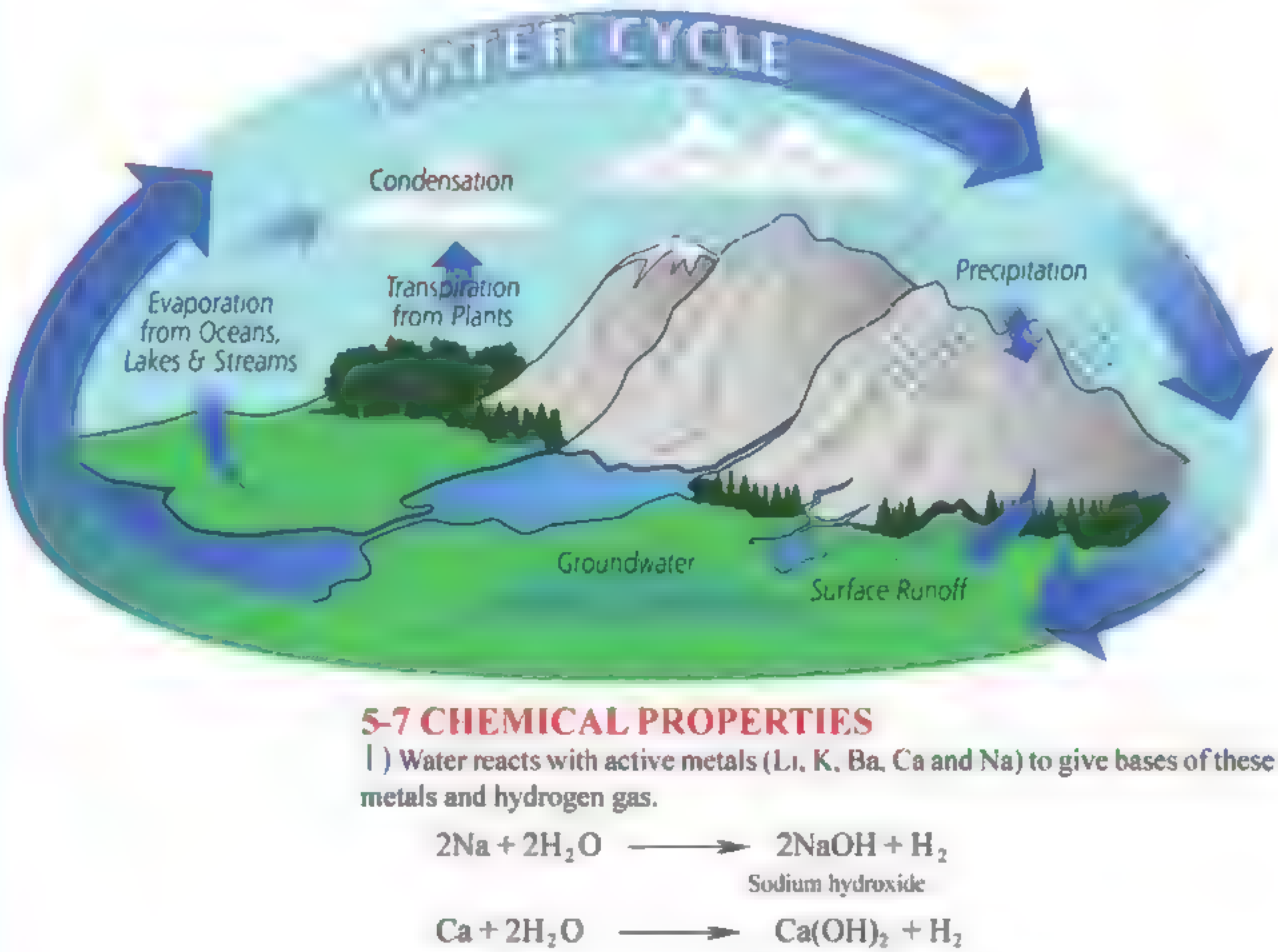
5-6 WATER CYCLE

1. Water evaporates from oceans, lakes and streams

2. The water vapor formed condenses in the upper regions of the atmosphere.

3. Vapor further condenses into larger drops which fall as rain.

4. This rain water slowly passes through the soil back to streams, lakes and oceans



5-7 CHEMICAL PROPERTIES

1) Water reacts with active metals (Li, K, Ba, Ca and Na) to give bases of these metals and hydrogen gas.

$$2Na + 2H_2O \longrightarrow \underset{\text{Sodium hydroxide}}{2NaOH} + H_2$$

$$Ca + 2H_2O \longrightarrow \underset{\text{Calcium hydroxide}}{Ca(OH)_2} + H_2$$

2) Less active metals such as iron and zinc react with water only at high temperature. The products of these reactions are metal oxide instead of hydroxide.

$$Zn + H_2O \xrightarrow{\text{heat}} ZnO + H_2$$

3) Water reacts with basic oxides to produce bases.

$$Na_2O + H_2O \longrightarrow 2NaOH$$

4) Water reacts with acidic oxides to produce acids

$$SO_2 + H_2O \longrightarrow H_2SO_4$$

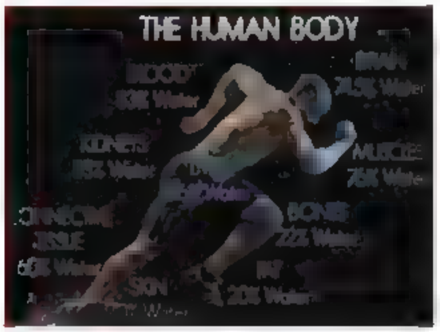
sulfuric acid

5-8 uses

In industry water is mainly used for cooling and as a solvent. Water cools automobile engines and nuclear power plants. Water is also used in the production of steel and paper. Water is used in the home for cooking, drinking and washing. Water in the form of steam is used to generate electricity. It is used to extract oil, sulfur and sodium chloride from the earth, and in the manufacture of several chemicals such as nitric and sulfuric acid.

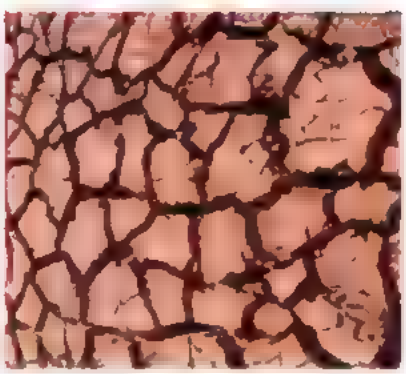
reading

Water

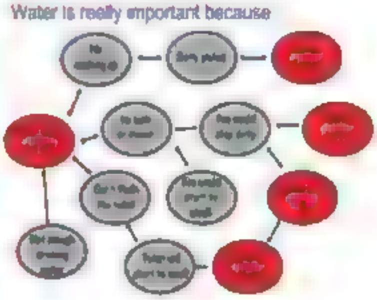


why water is important

Water makes up most of the world: the planet is seventy five percent water. Your brain is made almost entirely of water: seventy five percent of your brain is water. Trees are almost entirely water: seventy five percent of a tree is water.
People need to drink at least eight glasses of water each day to stay healthy.
Water is used to clean things-everything from our dinner plates to our bodies.
While a person can live for a few weeks without eating any food, that same person can only live a few days without water.
Water is used as temperature control both for our bodies as well as our planet.
Water gets rid of body waste and can help with a number of health concerns: constipation, functioning of the endocrine glands, muscle tone, kidney function, metabolization of fat and, obviously, dehydration. Water carries oxygen and other nutrients to the body's cells Water helps the body convert food into energy.



Water protects the body's organs Ninety percent of a person's blood and ninety percent of a tree's sap is made of water. Water can absorb energy vibrations. Earthquakes that happen under the ocean are rarely felt on land.
Water is what tells a seed to grow. You can plant a seed in soil, but if you do not give it water, it will never grow into a plant. The water is what splits the outer coat of a seed exposing the "embryo" to the oxygen in the soil that helps it to start growing. Water is also how the seed gets the nutrients it needs from the soil.
Without water, living things would be mired in their own waste. Water moves the waste away and cleanses the earth to keep it clean. If something doesn't stay clean, it can't stay healthy.
Water, when boiled, can kill the bacteria and other harmful agents found on food or plates. This is the only way to make sure that something is completely clean and safe for use.



Water is also the only substance that can get the dirt and bacteria off of our bodies.
Without water, there would not be life. Even the single celled organisms need water in which to live. It was from the water that life began. Water is also the only element that can exist in all three states: gas, solid and liquid and all three states are beneficial to humans. It is very easy to take our water for granted. It has always been here-in fact, the water on the planet today is likely the same water on that was on the planet even before the dinosaurs roamed it. Why is water important? Because without it, we would not exist.

CHAPTER QUESTIONS 05

5-1 What is the chemical formula of water?

5-2 Why water is important in our life?

5-3 Explain the electrolysis of water.

5-4 Explain the water cycle.

5-5 Write the uses of water.

5-6 Complete the following reactions.

1) $Zn + H_2O \xrightarrow{heat}$ .... $+ H_2$

2) $Na_2O + H_2O \longrightarrow$ ....

3) .... + ... $\longrightarrow H_2SO_4$

4) .... $\longrightarrow 2H_2 + O_2$

5) $Ca + 2H_2O \longrightarrow$ ....

5-7 What percentage of our body and world is water?

5-8 What are the constituents of water?

5-9 Explain the preparation methods of water by giving examples.

5-10 How much of Earth's surface is covered with water?

A) 2%

B) 3%

C) 75%

D) 97%

5-11 What are the three states of water on Earth?

A) Groundwater, lakes, and clouds
B) Liquid water, ice, and water vapor
C) Gas, steam, and vapor
D) Groundwater, oceans, and ice

5-12 "Condensation is an important process in the water cycle."
What forms because of condensation?

A) Water vapor B) Clouds
C) Rain D) Snow

CHAPTER 06

ACIDS, BASES AND SALTS

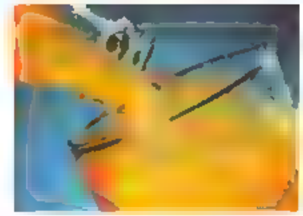
ACHIEVEMENTS

After complete studying this chapter, the student should be able to:

* recognize the materials we use in our lives and that contain acids and bases.
* understand the meaning of the acid base and salt.
* named acids and bases and salts.
* recognize the properties of acids bases and salts.
* know methods of preparation of acids and bases and salts.
* distinguish between acidic and basic solutions and neutral.
* measuring the pH of the solution.
* recognize the types of acids, bases and salts.

6-1 INTRODUCTION

There are many different chemical compounds. These compounds can be classified according to their properties. Three groups of compounds are **acids, bases and salts.** In our daily life, you use or come into contact with compounds in each of these groups. Many foods, such as lemons, tomatoes, vinegar, apples, and milk contain acids. Common cleaning agents, such as ammonia and lye are bases. Sodium chloride is a salt which is essential for good health. You will learn more about each of these important groups of compounds.



Some acids found in our food.

6-2 ACIDS

Acids are one of the most important classes of compounds in inorganic chemistry. They are so common that we face with them in some form everyday. The sourness of lemonade, the fizz of fizzy drinks and the distinctive taste of vinegar all come from acids. Car batteries use sulfuric acid, and many cleaning materials contain hydrochloric acid. We eat tomatoes containing ascorbic acid and drink coke containing carbonic acid.

The word acid comes from the Latin word "acere", which means sour.

Acids have a sour taste and are very corrosive and irritant. Most acids are soluble in water. Aqueous solutions of acids conduct electricity. In normal conditions many acids are liquids (HNO_3, H_2SO_4), while some of them are solid ($HSiO_3$, H_3PO_4) . Some volatile acids (HCl, HNO_3) have a characteristic odor.

Acids are corrosive substances. Sulfuric acid, nitric acid and hydrochloric acid (H_2SO_4 , HNO_3 and HCl) are the most dangerous. They can corrode paper, wood and organic tissue.

In 1887, a Swedish chemist, Arrhenius, defined acids as substances that dissolve in water by producing a hydrogen ion, H^+. This definition is valid for most acids.

$$HCl_{(g)} \xrightarrow{H_2O} H^+_{(aq)} + Cl^-_{(aq)}$$

Acids are often shown as HA, where H is hydrogen and A is the acidic negative ion But not all compounds containing hydrogen are acids. For example, methane (CH_4) glucose ($C_6H_{12}O_6$) and ammonia (NH_3) are not acids.

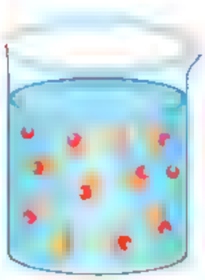
Acid	Where it is found
Hydrochloric acid	In the stomach
Citric acid	Lemon and orange
Ascorbic acid	Tomatoes
Folic acid	In green leafy vegetables
Formic acid	Insect bites and stinging nettles
Malic acid	Apples and pears

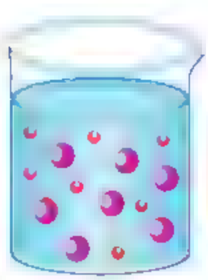
HCl

Hydrochloric acid is found in the stomach. Although it is one of the strongest acids, it does not damage the stomach lining.

Some examples of strong and weak acids

Strong Acids	Weak Acids
HCl	HF
HBr	HCN
HI	H_2CO_3
HNO_3	H_2SO_3
$HClO_4$	H_3PO_4
H_2SO_4	CH_3COOH





6-2-1 The Naming of Acids

Acids containing only two types of atoms are called **binary acids.** These acids do not have oxygen in their structures. Their names follow the form *hydro + (nonmetal) + ic + acid.*

Formula	Name
HCl	Hydrochloric acid
HI	Hydroiodic acid
HF	Hydrofluoric acid
H_2S	Hydrosulfuric acid

Acids are that contain oxygen are called oxyacids. In **oxyacids**, in addition to hydrogen and a nonmetal, a third element, oxygen, is present. If there is only one possible oxyacid, the *suffix ic* is used to name the acid. For example, H_3BO_3 is named boric acid and H_3PO_4, as phosphoric acid. If a non-metal can form more than one oxyacid, the acid containing more oxygen atoms will be named using the *suffix – ic*, and the acid containing less oxygen atoms is named using the *suffix – ous*.

Formula	Name
H_2SO_4	Sulfuric acid
H_2SO_3	Sulfurous acid
HNO_3	Nitric acid
HNO_2	Nitrous acid

6-2-2 The Classification of Acids

According to Strength

Acids do not all ionize or dissociate to the same extent. Some acids ionize completely in water, some partially. Thus acids are not all of equal strength in terms of the production of H^+ ions in solution. If an acid ionizes completely, it is a strong acid. For instance, HCl is a strong acid: HCl pass through water, almost all the molecules ionize to give H^+ and Cl^- ions. If an acid ionizes partially, on the other hand it is a weak acid. In the ionization of weak acids, some of the ions recombine and remain as molecules. HF is a weak acid. If you pass hydrogen fluoride gas through water, some of it will ionize to give H^+ and F^-. However, most of the dissolved hydrogen fluoride will remain as HF molecules in water.

According to the Number of Hydrogen Atoms

The simple formula of acids is HA. However, different acids going to produce one, two or three H^+ ions per molecule in their aqueous solutions. According to the number of H^+ ions are produced, acids are classified as monoprotic, diprotic or triprotic.

For example, hydrochloric acid is monoprotic because each HCl molecule ionizes to give one H^+ ion:

$$HCl_{(g)} \xrightarrow{H_2O} H^+_{(aq)} + Cl^-_{(aq)}$$

Similarly, sulfuric acid is diprotic:

$$H_2SO_{4(l)} \xrightarrow{H_2O} 2H^+_{(aq)} + SO_{4\,(aq)}^{2-}$$

and phosphoric acid is triprotic:

$$H_3PO_{4(s)} \xrightarrow{H_2O} 3H^+_{(aq)} + PO_{4\,(aq)}^{3-}$$

[illegible]	[illegible]	[illegible]
HCl	H_2SO_4	H_3PO_4
HNO_3	H_2CO_3	H_3AsO_4
HCN	H_2SO_3	

6-2-3 Chemical Properties of Acids

Acids are chemically active substances, so they can react with many other chemicals. Several acids ionize when added to water. These ions make aqueous solutions of acids which conduct electricity.

$$HCl_{(g)} \xrightarrow{H_2O} H^+_{(aq)} + Cl^-_{(aq)}$$

The ionization of acids in water produce heat. Certain amount of energy is released when a concentrated acid is added to water. Therefore, you should be careful while adding concentrated acid to water.
The same equation is often shown as

$$HCl_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl_{(aq)}$$

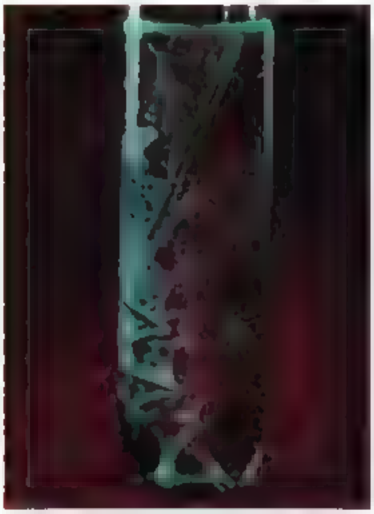
Acids can also act on indicators. Indicators are substances that change their color depending on the acidic or basic character of the media. Litmus paper and methyl orange are two important examples of indicators. Acid solutions change blue litmus paper to red.
If you add methyl orange to an acid solution, the solution becomes red.

Strong acids are very corrosive. They can eat away metal skins and clothes.

Indicators are usually weak acids or bases.

Colors of some indicators in acidic solutions

Indicator	Color in acidic solution
Litmus paper	Red
Methyl orange	Red
Phenolphthalein	Colorless
Bromothymol blue	Yellow



Aluminum reacts with hydrochloric acid to give hydrogen gas.

Exercise 6-1

Write the equations for the reactions of magnesium and aluminum with hydrofluoric acid and hydrosulfuric acid (four equations in total).

The most common and important reaction of bases is that with acids. Bases react with acids to give salt and water. Such reactions are called **neutralization reactions.** Both alkalis and insoluble bases are capable of reacting with acids.

Acid	+	Base	→	Salt	+	Water
HCl	+	NaOH	→	NaCl	+	H_2O

Hydrochloric acid + Sodium hydroxide → Sodium chloride + Water

Acids react and give displacement reactions with the metals that are more active than hydrogen. That is why such reactions are described as corrosive, meaning they "eat away" other materials.

$$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$$

$$Zn_{(s)} + H_2SO_{4(aq)} \rightarrow ZnSO_{4(aq)} + H_{2(g)}$$

6-3 BASES

Bases are substances known as the "opposite" of acids. Like acids, they must be handled carefully, because bases, especially the strong ones, are capable of destroying the texture of anything or eating away its substance by chemical action. All bases taste bitter. They have a slippery feeling. Simply, bases are the compounds of metals with hydroxide, OH^-.

Cleaning materials often contain bases. Ammonia solutions are widely used as household cleaners and detergents. Sodium hydroxide and potassium hydroxide are used in the production of soap. In medicine, some bases are used to prepare antacid tablets.

Toohtpaste has basic properties.

Water soluble bases are called **alkalis** and they can easily give OH– ions when they are put into water. Most alkalis are solid. However, in the laboratory their solutions are used:

$$NaOH_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$$

$$Ca(OH)_{2(s)} \xrightarrow{H_2O} Ca^{2+}_{(aq)} + 2OH^-_{(aq)}$$

Bases can be shown as $Me(OH)_X$, where "Me" refers to a metal and "x" shows the number of hydroxides.

Solid soaps are produced by using NaOH. In the production of liquid soaps KOH is used.

Ammonia, NH_3, is an exceptional base. It does not contain metal or hydroxide. However, when it is passed through water, the solution produced contains OH^- and acts as an alkali.

$$NH_{3(aq)} + H_2O_{(l)} \rightarrow NH_4^+{}_{(aq)} + OH^-_{(aq)}$$

Antacid tablets, containing bases such as $Mg(OH)_2$, $Al(OH)_3$, can neutralize excess acid in your stomach.

Bases are often prepared from the reactions of active metals (Li, K, Ba, Ca and Na) or hydrides of these metals with water. Such reactions give bases and hydrogen gas:

$$Na + 2H_2O \rightarrow 2NaOH + H_2$$
$$CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + 2H_2$$

6-3-1 The Naming of Bases

In the naming of bases, the word 'hydroxide' is added after the name of the metal. Do not forget to write the valency of the metal if it can take more than one valencies.

Formula	Name
NaOH	Sodium hydroxide
LiOH	Lithium hydroxide
$Mg(OH)_2$	Magnesium hydroxide
$Ca(OH)_2$	Calcium hydroxide
$Ba(OH)_2$	Barium hydroxide
$Fe(OH)_2$	Iron(II) hydroxide

Systematic and common names of some bases.

$Mg(OH)_2$	Magnesium hydroxide	Milk of magnesia
$Ca(OH)_2$	Calcium hydroxide	Slaked lime
NaOH	Sodium hydroxide	Caustic soda

6-3-2 The Classification of Bases

According to Strength

Bases that completely ionize in water are called strong bases. The bases of alkali metals (Group IA) and some alkaline earth metals (Group IIA) are strong. NaOH, KOH and $Ba(OH)_2$ are examples of strong bases. Their aqueous solutions conduct electricity well.

Bases that dissociate in water slightly are weak bases. Ammonia, NH_3 and magnesium hydroxide, $Mg(OH)_2$ are both weak bases. Water solutions of weak bases are poor conductors of electricity.

6-3-3 Chemical Properties of Bases

The chemical properties of bases vary according to their water solubilities. Alkalis are soluble in water so they change the color of indicators. In alkali solutions, red litmus paper turns to blue, phenolphthalein turns to pink, and methyl orange turns to yellow.

The most common and important reaction of bases is that with acids. Bases react with acids to give salt and water. Such reactions are called **neutralization reactions**. Both alkalis and insoluble bases are capable of reacting with acids.

Indicator	Color of basic solutions
Litmus paper	Blue
Methyl orange	Yellow
Phenolphthalein	Pink/Violet
Bromothymol blue	Blue

Exercise 6-2

Write the equations for the reactions of nitric acid with the following compounds.

a. Sodium hydroxide
b. Copper (II) hydroxide
c. Iron (III) hydroxide

Acids change litmus paper into red and bases change litmus paper into blue.

Red litmus paper with a drop of base here

Blue litmus paper with a drop of acid here

Base + Acid → Salt + Water

$$NaOH + HCl \rightarrow NaCl + H_2O$$

$$3Ba(OH)_2 + 2H_3PO_4 \rightarrow Ba_3(PO_4)_2 + 6H_2O$$

Ammonia can react with acids. However, such neutralization reactions give only salt, not water:

$NH_3 + HNO_3 \rightarrow NH_4NO_3$ and $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

Water insoluble bases decompose on heating to give metal oxides and water:

$$Mg(OH)_2 \xrightarrow{heat} MgO + H_2O$$

Alkalis can also react with amphoteric metals such as zinc and aluminum. When zinc reacts with sodium hydroxide, sodium zincate salt and hydrogen gas is produced.

$$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2$$

However, most alkalis do not decompose:

$$KOH \xrightarrow{heat} \text{No reaction}$$

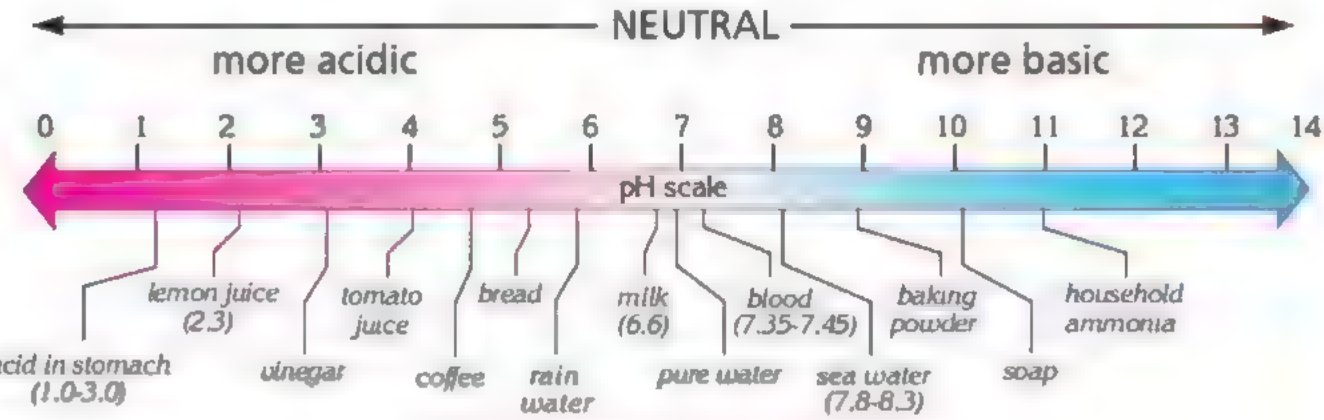
Comparison of properties acids with bases.

Properties of Acids	Properties of Bases
Have a sour taste.	Have a bitter taste.
Dissociate in water to give H^+ ions.	Dissociate in water to give OH^- ions.
Aqueous solutions conduct electricity.	Aqueous solutions conduct electricity.
Change the color of litmus paper to red.	Change the color of litmus paper to blue.
React with metals to give hydrogen gas and salt.	React with amphoteric metals to give hydrogen gas and salt and Water.
React with bases to produce salt and water.	React with acids to produce salt and water.

6-4 THE pH SCALE

In chemistry, pH is a numeric scale used to specify the acidity or basicity (alkalinity) of an aqueous solution.

The pH scale ranges from 0 to 14. A pH of 7 is neutral. Solutions with a pH less than 7 are acidic and solutions with a pH greater than 7 are basic.
Pure water is neutral, being neither an acid nor a base.



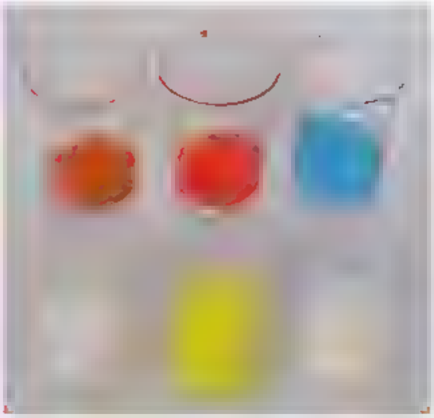
Acidity or basicity of various substances

pH is measured by using a pH meter (Figure 6-1) . A pH meter translates H^+ ion concentrations in a solution into an electrical signal that is converted into a digital display.

A less accurate way to measure pH is to use indicators. An indicator is a compound, such as phenolphthalein or methyl orange, that changes color reversibly at different pH values. For example, phenolphthalein is a colorless substance in any solution with a pH value smaller than 8.3. It turns red-violet in solutions with a pH value greater than 8.3.

Figure 6-1
A pH meter precisely measures the pH of a solution.

[illegible]	[illegible]	[illegible]
Phenolphthalein	[illegible]	Red
Methyl orange	Red	[illegible]
Litmus	Red	Blue



Salts may have a variety of colors.

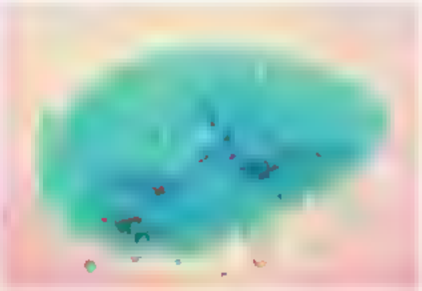
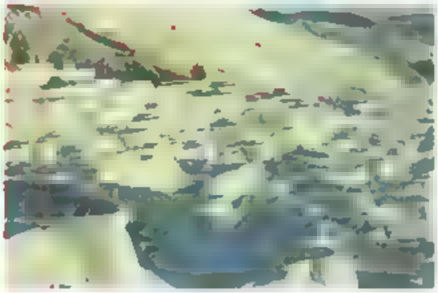


Table salt crystals obtained from sea water



Travertines, wich are formed by mineral waters containing calcium carbonate

6-5 SALTS

Salts are crystalline solids. They have ionic structure and therefore their boiling and melting points are high. Salts may have a variety of colors. For example, nickel (II) sulfate is green, lead (II) iodide is yellow and sodium chloride is white. Solubility is the mos t important characteristic property of salts. Many salts are soluble in water, but some are only slightly soluble and of course there are some salts which are insoluble in water. Aqueous solutions of salts conduct electricity.

A salt results when an acid (or acidic oxide) reacts with a base (or a basic oxide):

$$\underset{\text{base}}{NaOH} + \underset{\text{acid}}{HCl} \longrightarrow \underset{\text{salt}}{NaCl} + \underset{\text{water}}{H_2O}$$

$$\underset{\text{basic oxide}}{Na_2O} + \underset{\text{acidic oxide}}{SO_3} \longrightarrow \underset{\text{salt}}{Na_2SO_4}$$

6-5-1 The Naming of Salts

The names of salts are composed of the name of the metal first and then the name of the radical:

$NaCl$: Sodium chloride
$CaCO_3$: Calcium carbonate
$FeSO_4$: Iron (II) sulfate
$Fe_2(SO_4)_3$: Iron (III) sulfate

Salts of ammonia are called ammonium salts:

NH_4Br : Ammonium bromide
$(NH_4)_2SO_4$: Ammonium sulfate

6-5-2 Classification of Salts

When salts are dissolved in water, they may exhibit neutral, acidic or basic characteristics. Following this, salts are classified into three groups.

a) Neutral Salts

These are formed by the reactions of strong acids and strong bases. Aqueous solutions of neutral salts do not exhibit acidic or basic properties. NaOH is a strong base, HCl a strong acid. Therefore, t he salt that is formed by the reactions of these two compounds, NaCl, is a neutral salt. KNO_3, Li_2SO_4 and $NaClO_4$ are some other examples of neutral salts.

b) Acidic Salts

Acidic salts are formed by the reaction of strong acids with weak bases. They have acidic properties. $FeCl_2$, $CuSO_4$ and NH_4NO_3 are examples of acidic salts. Some salts that contain H^+ in their structure, like $NaHSO_4$, are also acidic because when they ionize in water they give H^+ ions to the media.

c) Basic Salts

Basic salts are produced from the reactions of weak acids with strong bases. They have basic properties. NaCN, NaF and Na_2CO_3 are examples of basic salts. Salts that produce OH^- ions in water, like CaOHCl, are also basic.

Common and systematic names of some salts are given below.

Formula	Systematic Name	Common Name
NaCl	Sodium chloride	Table salt
$CaCO_3$	Calcium carbonate	Limestone
Na_2CO_3	Sodium carbonate	Washing soda
KNO_3	Potassium nitrate	Saltpeter
$CaSO_4.2H_2O$	Calcium sulfate dihydrate	Gypsum

6-5-3 Chemical Properties of Salts

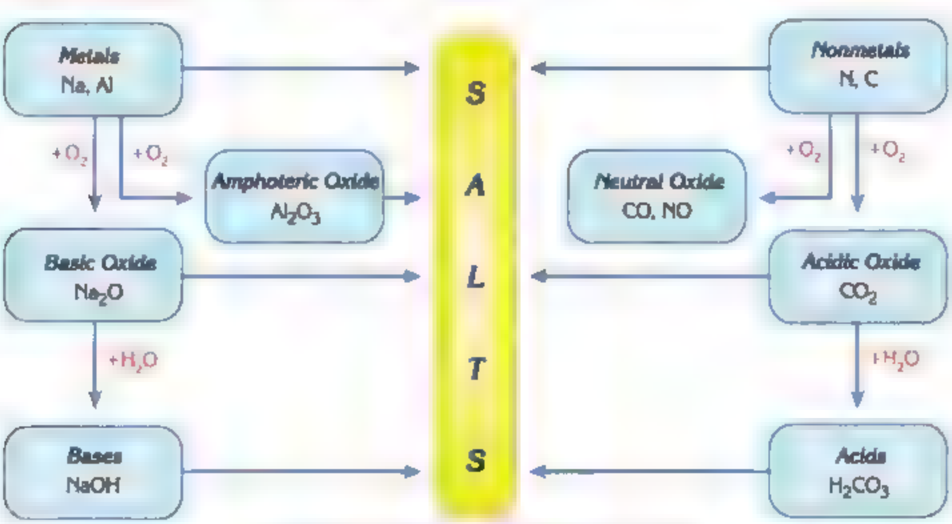
Salts are selective in their reactions. They react with other substances only under certain conditions. For example, they may react with metals but only if the free metal is more active than the metal of the salt. Consider the following reaction:

$$Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$$

Remember the common strong acids: HCl, HNO_3, H_2SO_4, HBr, HI and $HClO_4$. HCl and HNO_3 are volatile acids.

This reaction takes place because copper is more active than silver. However, if you put silver particles in a copper (II) nitrate solution, no reaction takes place as silver is less active than copper.

$$Ag + Cu(NO_3)_2 \rightarrow \text{no reaction}$$



Transformation of inorganic compounds with salts

CHAPTER QUESTIONS

6-1 Give three common properties of acids.

6-2 What is the definition of an acid according to Arrhenius?

6-3 Write the equations for the ionization of HNO_3, H_2SO_3

6-4 Three common acids of sulfur are H_2S, H_2SO_3 and H_2SO_4. Give the names of these acids.

6-5 What is the difference between strong and weak acids? Give three examples for each group.

6-6 How are the acids classified according to number of hydrogen atoms?

6-7 Explain the effect of acids on methyl orange and litmus paper.

6-8 Metals react with acids to give hydrogen gas and salts. Write the equations for the reactions of magnesium and aluminum with hydrochloric acid.

6-9 What are the names of the following compounds?

a. $Ca(OH)_2$ **b.** $Fe(OH)_2$
c. $Zn(OH)_2$

6-10 How do bases effect litmus paper, phenolphthalein and methyl orange?

6-11 What is a neutralization reaction? Give three examples of such reactions.

6-12 Compare the properties of bases with those of acids.

6-13 Complete and balance the following equations:

a. $KOH + HBr \longrightarrow$

b. $Ba(OH)_2 + 2H_3PO_4 \longrightarrow$

c. $NH_3 + HNO_3 \longrightarrow$

d. $NH_3 \xrightarrow{\text{heat}}$

e. $Fe(OH)_3 \xrightarrow{\text{heat}}$

6-14 Which types of salts do you know? Give two examples for each.

6-15 Classify the following salts as either acidic, basic or neutral:
NaBr, Na_2CO_3, CaOHCl, $BaSO_4$, NH_4Cl, $CaCO_3$ and $KHSO_4$.

6-16 Explain the formation of acidic, basic and neutral salts. Give two examples for each.

6-19 Choose the correct answer for the following questions.

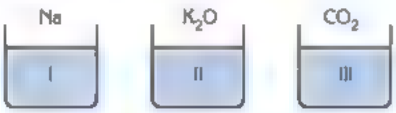
1. Two of the reactions of element X are given below. What type of an element can X be?

$X + 2HCl \rightarrow XCl_2 + H_2$

$X + 2NaOH \rightarrow Na_2XO_2 + H_2$

A) Non metal **B)** Inert metal
C) Amphoteric metal **D)** Halogen
E) Alkali metal

2. Three containers are filled with water To the first and second container respectively, sodium metal and potassium oxide are added. Carbon dioxide is passed through the third container.



Which one of the following is correct for the final solutions?

	I	II	III
A)	Acidic	Basic	Acidic
B)	Basic	Acidic	Basic
C)	Basic	Basic	Acidic
D)	Acidic	Acidic	Basic
E)	Basic	Basic	Basic

3. Which of these properties is valid for both acids and alkalis?
I. Aqueous solutions conduct electricity.
II. Dissociate into ions in water.
III. React with magnesium metal.

A) I only
B) I and II
C) II and III
D) I and III
E) I, II and III

4. Which of these statements is/are true for strong bases?
I. They give hydroxide ions when they dissociate in water.
II. They form neutral salts with strong acids.
III. Their aqueous solutions change the color of litmus paper to red.

A) I only **B)** II only
C) I and II **D)** I and III
E) II and III

5. Which of the these is/are correct for basic oxides?
I. They react with acids.
II. They react with bases.
III. They react with neutral oxides.

A) I only **B)** II only
C) III only **D)** I and III
E) II and III

6. Which one of the following is wrong for acids?

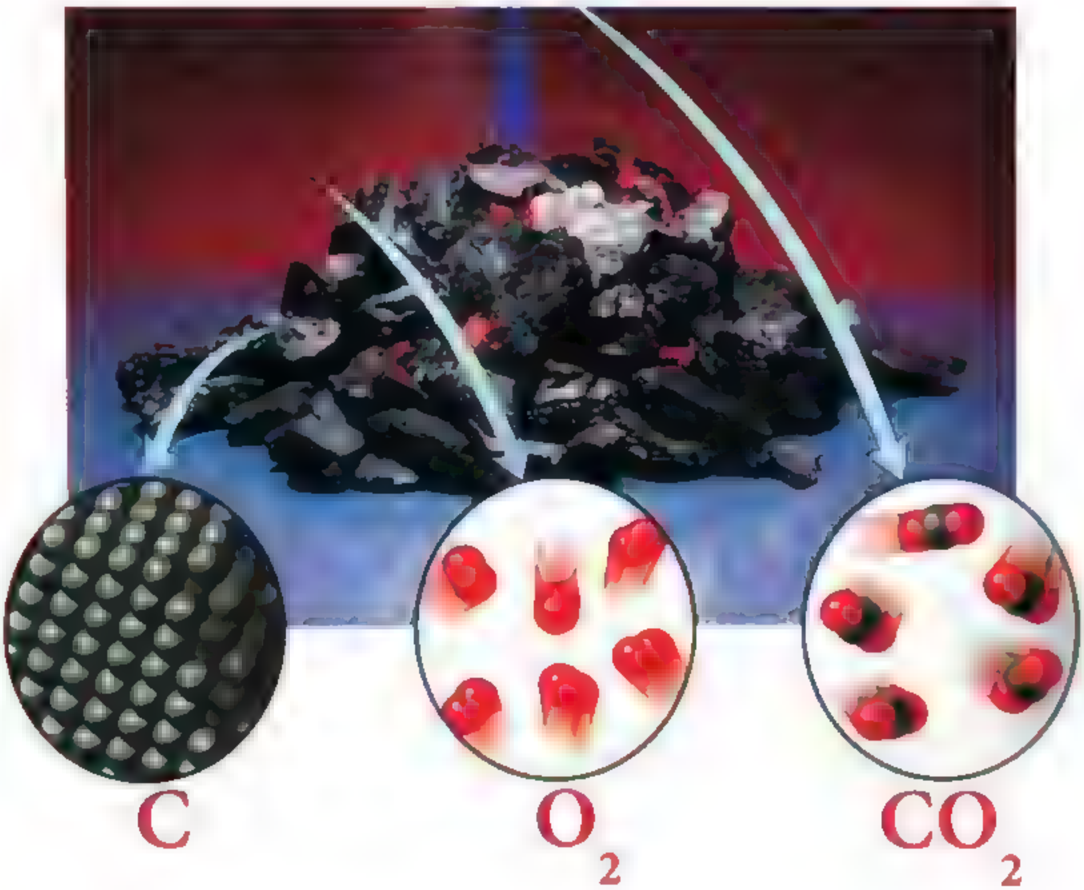
A) Their aqueous solutions conduct electricity.
B) They have sour taste.
C) They produce H+ ions in water.
D)They change the color of litmus paper to blue.
E) When they react with magnesium metal, hydrogen gas is evolved.

7. The substances X, Y and Z are added to three different containers containing water. When litmus is dipped into the resulting solutions, it becomes red in the first one, and blue in the second and third ones. Which one of the following may be correct for X, Y and Z?

	X	Y	Z
A)	NaOH	NH_3	H_2SO_4
B)	H_2SO_4	NaOH	NH_3
C)	NH_3	H_2SO_4	NaOH

CHAPTER 07

CARBON



ACHIEVEMENTS

After complete studying this chapter, the student should be able to:

* understand the importance of carbon.
* know the allotropes of carbon.
* learn properties of carbon.
* learn the carbons compounds.
* know the physical and chemical properties of carbon.
* learn the uses of carbon

1. CARBON

Carbon has an atomic number of 6

symbol of energy level	Energy level (n)	number of electrons
K	1	2
L	2	4

There is an enormous number of carbon compounds when compared with other elements. ***Carbon is the basic element of living organisms.*** In our daily life, it is found as petroleum and its by-products. For that reason, carbon chemistry has become a special branch of chemistry called organic chemistry. However, in this chapter, we will only investigate the inorganic compounds of carbon.

Up to now, about 6 million organic compounds have been synthesized, and evidence of 15 million organic compounds is known theoretically.

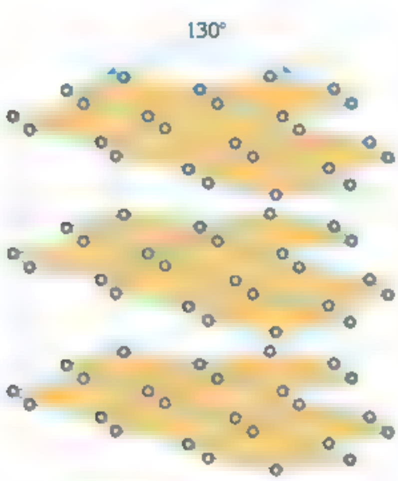


Figure 2a The structure of diamond.

Figure 1 Allotropes of carbon

DIAMOND	GRAPHITE
- the hardest substance in nature - nonconductor - used as an abrasive - transparent	- soft - good conductor - used as a lubricant - dark black

Carbon has a crystalline lattice structure. There are strong covalent bonds between its atoms. Because of these strong bonds, carbon has the highest melting and boiling points in the group. Carbon has two allotropes of major importance in daily life. They are graphite and diamond (Figure 1).

The different types of bonds between the atoms of carbon cause the differences in appearance and physical properties of these two allotropes.

Graphite is a soft, dark black solid with a metallic shiny color. It is a very good conductor of electricity, so it is used as electrodes in dry cells. In pencils, a graphite and clay mixture is used.

Graphite crystals have a layered structure formed by hexagonal carbon cycles. These layers slide over each other easily because they are bonded to each other with weak bonds shown in Figure 2b. Because of this motion, graphite conducts heat and electricity, and has a low melting and boiling point in comparison to diamond.

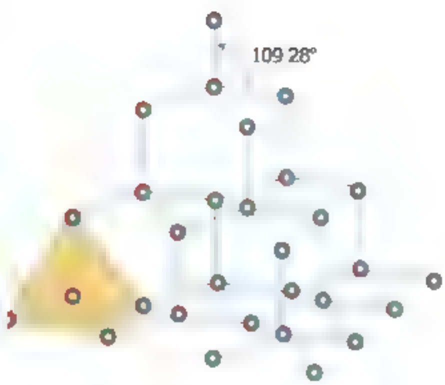


Figure 2b The structure of graphite

Diamond is formed naturally by the transformation of graphite exposed to high underground pressure over millions of years. Pure diamond is a transparent solid. Each carbon atom in the structure of diamond is bonded with strong bonds to 4 neighbor carbon atoms in the shape of a tetrahedron shown in Figure 2a. For these reasons, diamond is the hardest natural mineral, and has a high melting point (≈ 3500°C) and boiling point (≈ 4850°C). It does not conduct electricity and tends to change into graphite which is more stable thermodynamically.

$$C_{(diamond)} \longrightarrow C_{(graphite)} + 1.9\ kJ$$

Coal

Artificial diamond is obtained by changing the crystalline structure of graphite under high pressure and temperature. Such a diamond does not have any value as jewelry. Because of its hardness, it is used to cut hard materials in industry. In addition to these allotropes, carbon is found naturally in the forms of coal, coke, charcoal and soot, but they are not in crystalline forms. They are amorphous solids with wide surfaces.

Fullerenes

In 1985, another allotropic form of carbon was discovered. There are two important forms of these new allotropic forms, C_{60} and C_{70}. The general name of them is fullerenes. The structure of a fullerene, C_{60}, is given below in Figure 4.

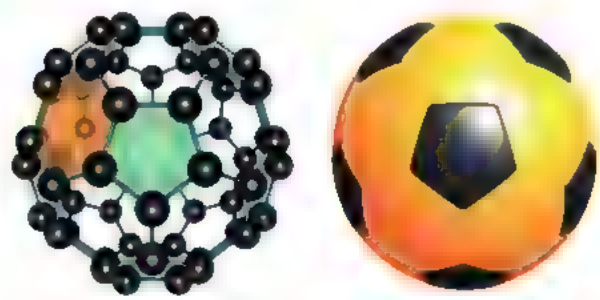


Figure 3 Buckminsterfullerene (C_{60}) has a stable "soccer-ball" structure

These molecular forms of carbon have been studied intensively. C_{60} has a stable "soccer-ball" structure. In that structure, there are hexagonal and pentagonal structures. Today we can produce C_{60} from graphite by laser technology.

Fullerenes are used especially in preparation of super conductors.

1.4 OCCURRENCE

Carbon makes up only 0.91% of the earth's crust. Free carbon is found in nature as diamond and graphite. It is also found in natural gas and petroleum as its compounds, in the atmosphere as carbon dioxide (CO_2), and in the earth's crust as its carbonates (Table 2).

Table 2 Carbonate minerals in earth's crust

Chemical formula	Common name	Chemical name
$MgCO_3$ $CaCO_3$	Dolomite	Magnesium calcium carbonate
$CuCO_3.Cu(OH)_2$	Malachite	Copper II hydroxy carbonate
$CaCO_3$	Marble, limestone	Calcium carbonate
$FeCO_3$	Siderite	Iron II carbonate
$BaCO_3$	Witherite	Barium carbonate

Apart from the compounds and minerals of carbon in the earth's crust, carbon is the basic element in living organisms. For example, in the structure of proteins, saccharides and amino acids, carbon is the main element.

7.2 CHEMICAL PROPERTIES

Carbon is a nonmetal. It has an atomic number of 6 and it takes oxidation states between –4 and +4.

carbon can form ionic compounds with active metals, such as Al_4C_3 and CaC_2. But it tends to make covalent bonds by sharing its valence electrons. This property allows it to form a vast number of compounds.

Reactions

Some important reactions of carbon are as given below.

1. Graphite burns easily, but diamond hardly burns. The burning product at low temperature is carbon dioxide.

$$C\text{ (graphite)} + O_2(g) \rightarrow CO_2(g) + 393.5\text{ kJ}$$

The burning product at high temperature and in limited oxygen is carbon monoxide

$$2C(s) + \underset{\text{limited}}{O_2(g)} \longrightarrow 2CO(g) + 220.7\text{ kJ}$$

CO is not stable and decomposes to form CO_2 and C.

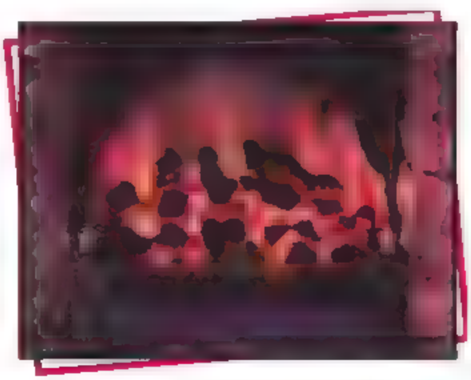
$$2CO(g) + O_2(g) \longrightarrow 2CO_2(g) + 566.0\text{ kJ}$$

In a coal fire the main reaction is.

$$C + O_2 \longrightarrow CO_2$$

But at high temperature and in limited oxygen, the burning product changes to carbon monoxide

$$2C(s) + \underset{\text{limited}}{O_2(g)} \longrightarrow 2CO(g)$$



2. Carbon is not affected by acids and bases, but it is oxidized by hot, concentrated HNO_3 and H_2SO_4.

$$C_{(s)} + 4HNO_3(\text{conc.}) \rightarrow CO_{2(g)} + 4NO_{2(g)} + 2H_2O_{(l)}$$

$$C_{(s)} + 2H_2SO_4(\text{conc.}) \rightarrow CO_{2(g)} + 2SO_{2(g)} + 2H_2O_{(l)}$$

3. Carbon reacts with steam at very high temperature.

$$C_{(s)} + H_2O(g) + \text{heat} \rightleftharpoons \underbrace{CO_{(g)} + H_{2(g)}}_{\text{water gas}}$$

The gas mixture formed in this reaction ($CO - H_2$) is called water gas, and is used as a fuel.

4. Carbon forms carbides by reacting with metals at high temperatures.

$$2C + Ca \xrightarrow{\text{heat}} \underset{\text{calcium carbide}}{CaC_2}$$

5. Carbon react with sulfur. in high tempreture

$$C + 2S \xrightarrow{700 - 800\ ^\circ C} CS_2$$

The compounds of carbon with elements having low electronegativity are called carbides. For example, CaC_2 is calcium carbide, Al_4C_3 is aluminum carbide and SiC is silicon carbide.

EXTRA

Carbon monoxide is a poisonous gas, causing death in atmospheric concentrations as low as 0.5%. Therefore automatic detectors must be used in places where the release of CO is expected. Fuels should not be burned in homes or in stores that do not have proper ventilation to ensure a good supply of air.

If carbon monoxide is inhaled it combines in the lungs with the hemoglobin in red blood cells and changes it into carboxy hemoglobin that can not carry oxygen (Figure 6).

As a result, unconsciousness occurs. If excess CO is inhaled it may cause death.

In cases of CO poisoning, medical experts advise that the patient be removed to fresh air as quickly as possible.

Figure 6
CO is one of the gases produced while cooking meat on a barbecue.

Preparation

Atmospheric CO forms in incomplete reactions of carbon compounds with oxygen

$$\underset{\text{octane}}{2C_8H_{18(l)}} + 17O_{2(g)} \longrightarrow \underset{\text{carbon monoxide}}{16CO_{(g)}} + 18H_2O_{(l)}$$

In industry two methods are used to prepare carbon monoxide.

In the first, CO_2 is reduced by carbon.

$$CO_{2(g)} + C_{(s)} \longrightarrow 2CO_{(g)}$$

In the second, formic acid, HCOOH, is dehydrated using concentrated sulfuric acid.

$$HCOOH \xrightarrow[-H_2O]{H_2SO_4} CO$$

6. Since carbon is a good reducing agent, it is used to produce metals from their oxides at about 600°C.

$$2CuO + C \longrightarrow 2Cu + CO_2$$

7. Carbon forms organic compounds in reaction with H_2.

$$C + 2H_2 \xrightarrow[Pt]{1500\ ^\circ C,\ pressure} CH_4 \uparrow$$

1.3 COMPOUNDS OF CARBON

In this section, the most common inorganic compounds of carbon will be considered in detail.

Figure 5 The structure of carbon monoxide.

1. Oxides

Carbon has two principal oxides: carbon monoxide and carbon dioxide.

a. Carbon monoxide, CO

Carbon monoxide is found in the atmosphere in trace amounts. It is a colorless, odorless and poisonous gas that is lighter than air. It is slightly soluble in water and its boiling point is –191.5°C.

The exhausts of motor cars and the combustion of fuels cause an increase in the concentration of carbon monoxide in air.

Chemical Properties

Carbon monoxide is neither acidic nor basic. It is a neutral oxide.

It is a strong reducing agent at high temperatures.

– It reduces metal oxides to metals.

$$ZnO_{(s)} + CO_{(g)} \xrightarrow{heat} Zn_{(s)} + CO_{2(g)}$$

– CO also reduces steam to hydrogen at 230°C.

$$H_2O_{(g)} + CO_{(g)} \overset{Fe_2O_3}{\rightleftharpoons} H_{2(g)} + CO_{2(g)}$$

Uses

As mentioned above CO is used as a reducing agent in the extraction of metals from their ores. It is also used as a gaseous fuel and as a primary substance in many organic synthesis reactions, such as methanol and formic acid.

b. Carbon dioxide, CO_2

Carbon dioxide is found in the atmosphere at around 0.03% by volume. It is a colorless, odorless and nonpoisonous gas. It is approximately 1.5 times heavier than air. CO_2 is moderately soluble in water. It solidifies at –78°C to form dry ice.

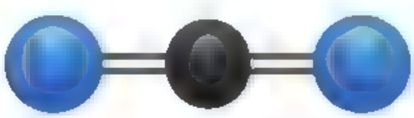


Figure 7 The structure of carbon dioxide.

Preparation

a. In Industry

CO_2 is produced when limestone is heated to make quicklime and by the fermentation of glucose.

$$\underset{\text{limestone}}{CaCO_3} \xrightarrow{1200°C} \underset{\text{quicklime}}{CaO} + CO_2\uparrow$$

b. In the Laboratory

1. By the action of dilute acids on metal carbonates and hydrogen carbonates.

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2\uparrow$$ (Figure 8)

2. After combustion reactions of carbon containing substances.

$$2C_2H_6 + 7O_2 \longrightarrow 4CO_2\uparrow + 6H_2O$$

Chemical Properties

Carbon dioxide is an acidic oxide. When it is dissolved in water, it forms carbonic acid, which is unstable.

$$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons \underset{\text{carbonic acid}}{H_2CO_{3(aq)}}$$

It reacts with basic oxides and bases

$$CO_{2(g)} + CaO_{(s)} \longrightarrow CaCO_{3(s)}$$

$$CO_{2(g)} + 2NaOH_{(aq)} \longrightarrow Na_2CO_{3(aq)} + H_2O_{(l)}$$

At high temperatures, CO_2 behaves like an oxidizing agent.

$$CO_{2(s)} + 2Mg_{(s)} \xrightarrow{1200°C} 2MgO_{(l)} + C_{(s)}$$

Detection of CO_2

We can detect the existence of carbon dioxide with limewater, $Ca(OH)_2$. When carbon dioxide is introduced into a solution of limewater, colorless limewater solution becomes turbid, and a milky white precipitate of calcium carbonate forms (Figure 9).

Figure 8 *Detection of CO_2 gas in the laboratory.*

The test reaction of carbon dioxide is:

$$CO_2(g) + Ca(OH)_{2(aq)} \longrightarrow CaCO_3(s) + H_2O(l)$$

If more CO_2 is added, excess carbon dioxide reacts with water to form H_2CO_3 and the milky solution becomes colorless. Carbonic acid reacts with calcium carbonate to form a colorless solution of calcium hydrogen carbonate, $Ca(HCO_3)_2$, as in the following reaction:

$$CO_2(g) + CaCO_3(s) + H_2O(l) \longrightarrow Ca(HCO_3)_2(aq)$$

Calcium hydrogen carbonate decomposes when heated. In that case a colorless solution of hydrogen carbonate again changes into the white insoluble product as, calcium carbonate, $CaCO_3$.

$$Ca(HCO_3)_2(aq) \xrightarrow{\text{heat}} CaCO_3(s) + H_2O(l) + CO_2(g)$$

USES

Carbon dioxide is used in fire extinguishers, carbonated drinks (soft drinks), medicine, manufacture of industrially important substances such as washing soda ($Na_2CO_3 \cdot 10H_2O$), yeast, baking powder, dry ice, coolant and preservation of fruits.

Solid CO_2 known as "dry [illegible]

— In fire extinguishers: Because carbon dioxide does not support most combustion, it is used in many fire-fighting situations. It is heavier than air, and as a result it cuts the interaction of air with the burning substance. Without air (oxygen), burning is impossible.

— As dry ice: The solid form of carbon dioxide is known as dry ice. It sublimes at -78 °C. It is used as a refrigerating agent.

— In soft drinks: it is used in soda-water and carbonated water.

— In synthesis of washing soda, $Na_2CO_3 \cdot 10H_2O$ and baking soda, $NaHCO_3$.

— In production of sugar during photosynthesis.

CHAPTER QUESTIONS

7-1 Choose the correct answer for the following questions.

1. What is the electron configuration of carbon $^{12}_{6}C$ element?

A) 2,4 B) 2,2,2
C) 2,8,2 D) 2,1,3

2. Which of the following define(s) carbon element?
I. It has a crystalline lattice structure.
II. Coke and diamond are allotropes of carbon.
III. It takes oxidation states between -4 and +4

A) I only B) II only
C) III only D) I and II
E) I, II and III

3. I. As a fire extinguisher.
II. In soft drinks.
III. As refrigerating agent
Which of the above is/are correct uses of carbon dioxide?

A) I only B) I and II
C) I and III D) II and III
E) I, II and III

4. Which one(s) can be formed under suitable conditions? If $C_{(s)} + H_2O_{(g)} \rightarrow$ ....

A) Carbon monoxide and methane
B) Carbon monoxide and hydrogen
C) Carbon dioxide and methane
D) Carbon dioxide and hydrogen
E) No reaction forms

5. Which of the given reactions is incorrect for CO_2 gas under the proper conditions?

A) $CO_{2(g)} + H_2O_{(l)} \rightarrow H_2CO_{3(aq)}$
B) $CO_{2(g)} + 2NaOH_{(aq)} \rightarrow Na_2CO_{3(aq)} + H_2O$
C) $CO_{2(g)} + CaO_{(aq)} \rightarrow CaCO_{3(s)}$
D) $2CO_{2(g)} + Ca(OH)_{2(aq)} \rightarrow Ca(HCO_3)_{2(aq)}$
E) $CO_{2(g)} + 2Mg_{(s)} \rightarrow 2MgO_{(s)} + C_{(s)}$

7-2 Fill in the blanks for the carbon family.

1. .... and .... have allotropes.
2. The most common allotropes of carbon are .... and ....
3. All members are found in .... state at 25 °C and 1 atm.

7-3 Compare the properties of diamond and graphite.

7-4 Why does graphite conduct electricity whereas diamond doesn't? Explain.

7-5 Complete the following reactions which form at suitable conditions and balance the equations.

1. $C + O_2(\text{excess}) \rightarrow$
2. $C + O_2(\text{limited}) \rightarrow$
3. $C + S \rightarrow$
4. $C + FeO \rightarrow$
5. $C + H_2 \xrightarrow{\text{heat, pressure}}$
6. $ZnO + C \xrightarrow{\text{heat, pressure}}$
7. $Fe_3O_4 + CO \rightarrow$
8. $CO_2 + Ca(OH)_2 \rightarrow$
9. $C + HNO_3 \rightarrow$

7-6 Draw a schema that shows the uses of CO_2

7-7 Which events in daily life cause the formation of CO_2?

7-8 What are the effects of increasing the amount of CO_2 in atmosphere?

Common Laboratory Apparatus and Equipment

Learning Objectives

- Laboratory
- Common laboratory apparatus and equipment
- Recording of an experiment
- Safety rules in chemistry laboratory

Chemistry is the branch of science which deals with the properties and reactions of substances. It helps us to understand the basic principles that govern the interaction of different substances.

Thirst for Knowledge

A person who studies chemistry is called a chemist.

Chemistry involves a lot of experimentation. An **experiment** can be defined as a test carried out under controlled conditions to demonstrate a known truth, examine the validity of a hypothesis or determine the efficacy of something previously untried.

LABORATORY

Have you seen a laboratory in your school? It is a place where experiments are carried out and analyses are performed to reach a conclusion.

Most laboratories are well-organized and clean places that have provisions to control conditions such as temperature, pressure, humidity, etc. A good chemistry laboratory is fully-equipped with the basic measuring and analytical laboratory apparatus that allow a good study of all the branches of chemistry.

Chemistry laboratory

A chemistry laboratory should be equipped with the following facilities:

1. **Working table:** It is a place where a chemist works. It should consist of gas taps, sink, reagent shelf, waste paper basket, a side shelf for keeping glassware apparatus, a fume closet and a gas cylinder.
2. **Reagent shelf:** All the reagents and chemicals should be kept in a reagent shelf with proper labels.
3. **Exhaust fans:** A laboratory should have exhaust fans on top of the walls with a vent to expel poisonous gases and fumes.

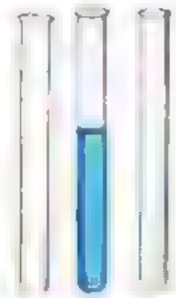
4. **Balance room:** There should be a balance room with a number of balances for weighing chemicals. It should be free of dust and smoke for accurate measurements.

COMMON LABORATORY APPARATUS AND EQUIPMENT

Apparatus is a group of materials or devices required to carry out experiments. They are used to measure, observe and compare things with greater accuracy. Common laboratory apparatus and equipments are described below.

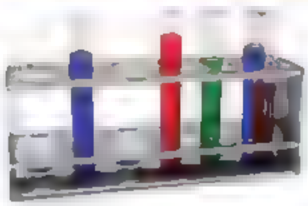
Test Tube

It is a cylindrical glass tube whose one end is open while the other closed end is curved outwards. There are different types of test tubes made of different types of glasses. Test tubes are available in different sizes. Test tubes are used for heating and boiling small quantities of chemicals.


Test tubes

Thirst for Knowledge

Test tubes that are made from expansion-resistant glasses such as pyrex can be placed directly over a Bunsen burner's flame. They are also called hard glass tubes or boiling test tubes.


Test tube stand or rack

Test Tube Stand or Rack

A test tube stand or rack is made up of steel, plastic or wood. It is used to keep test tubes. It has bars and holes to keep the test tubes in inverted or upright position respectively.

Test Tube Holder

It is a metallic rod with plastic or wooden handle at one end and a clamp at the other end. It is used to hold a test tube either while heating a substance or when strong chemicals like acids or alkalis are poured into another apparatus.


Test tube holder


Beaker

Beaker

It is an open glass container, cylindrical in shape, with a flat bottom and a lip for pouring. Beakers are available in a wide range of sizes and are made of different types of glasses. There are beakers with and without graduations. Beakers are used for stirring, mixing and heating solutions.

Round-bottom Flask

It is a glass container with spherical bottom and a narrow cylindrical neck. It is generally used for heating solutions. The round bottom of the flask allows uniform heating and/or boiling of solutions. Round-bottom flasks are available in many sizes.


Round-bottom flask

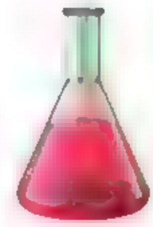
Flat-bottom flask

Flat-bottom Flask

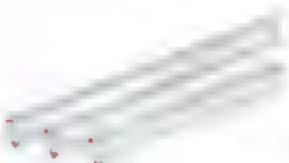
It is a flask which is similar to round-bottom flask but has a flat bottom that allows it to stand on a levelled surface. It is used for storing and mixing liquid chemicals. It is not used for heating purposes.

Conical Flask

A conical flask is also known as Erlenmeyer flask. It has a flat bottom, conical body and a cylindrical neck. It has markings on its outer surface to indicate the approximate volume of contents. It is often used to heat solutions and for titration experiments.



Conical flask



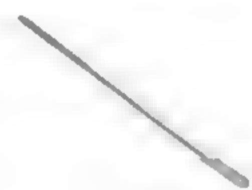
Glass tubing/ tube

Glass Tubing/Tube

It is a hollow piece of glass and is open at both the ends. It can be bent by heating to red hot over a non-luminous Bunsen flame, to transfer gases from one vessel to another.

Glass Rod

It is also known as stirring rod. It is a solid glass tube. It is used to stir solutions in flasks and beakers.



Glass rod

Funnel

Funnel

A funnel has a conical-shaped mouth and a long tapering neck. It is used to pour liquids or channel fine grained substances into containers with a small mouth. It is available in various sizes and is usually made of glass or plastic.

China Dish

It is also called an evaporating dish. It is made of porcelain. It is used to evaporate liquids by heating.

China dish

Pipette

Pipette

It is a long narrow tube with a nozzle at one end and a bulb in the middle. Nowadays, pipette with a rubber vacuum bulb is also available. A pipette is used to transfer a measured volume of liquid.

Note: You should never pipette any chemical using your mouth.

Burette

It is a long cylindrical graduated tube with stopcock near its bottom end. It is used for measuring and dispensing known amounts of liquids and is widely used in titration experiments.


Burette


Measuring cylinder

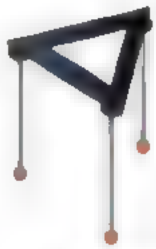
Measuring Cylinder

It is also called graduated cylinder. It is a cylindrical graduated glass or plastic vessel with a flat bottom and lip for pouring. A measuring cylinder is used to measure a fixed volume of liquid.

Iron Stand

It has a long iron rod fixed on a flat base. Clamps can be attached on the iron rod. It is used for holding apparatus such as round-bottom flasks or test tubes in a specific position.


Iron stand

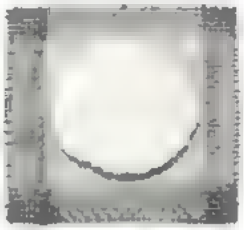

Tripod stand

Tripod Stand

It has three legs and a triangular base in the middle. It is made of iron. A tripod stand is used for supporting apparatus while heating.

Asbestos Wire Gauze

It is an iron wire mesh with thin asbestos in the middle. It is placed over the tripod stand to provide a stage for a glass apparatus while heating. It helps in even distribution of heat from the burner to the glass apparatus.


Asbestos wire gauze


Pestle and mortar

Pestle and Mortar

A pestle is a heavy baseball bat-shaped stick whose end is used for pounding and grinding. A mortar is a bowl in which the substance to be grind, crush or mix is kept. Pestle and mortar are made of porcelain, stoneware, marble and wood. They are used to crush, grind and mix solid substances.

Spirit Lamp


Spirit lamp

It is a device used for heating purposes. It burns alcohol or other liquid fuel. It has three parts—tank, neck and cap. The fuel is filled in the tank. A cotton wick that is immersed in the fuel passes through the neck. The cotton wick soaks up the fuel and burns when lighted. The flame of the spirit lamp is extinguished by carefully covering it with the cap (cover).

Note: A spirit lamp should never be extinguished by blowing air from the mouth.


Bunsen burner

Bunsen Burner

These days spirit lamps are replaced by another heating device called Bunsen burner. It consists of a mixing tube in which gas and air are mixed. The gas comes from the nozzle and air comes from the air holes. When ignited, it burns with a blue flame on top of the burner. The flame can be adjusted by opening or closing the adjustable air holes.

Spatula

It is like a spoon. It is used to take small quantities of solid chemicals.


Spatula


Dropper

Dropper

It is a long tube made up of glass or plastic with a vacuum bulb at one end. A dropper is used for drawing a liquid and releasing a very small quantity of it at a time.

Watch Glass

It is a circular, slightly concave piece of glass. It is used to evaporate a liquid, to hold solids while being weighed or as a cover for a beaker.


Watch glass


Analytical balance

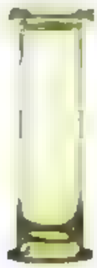
Analytical Balance

It is also called a balance scale or a laboratory balance. It consists of a horizontal metallic beam with a support and a pointer at its centre. The beam can move freely about the support. From the ends of the beam, two identical pans are suspended such that they are equidistant from the centre of the beam. This entire arrangement is kept inside a transparent enclosure with doors. This is done so that dust does not collect and any air current in the room does not affect the balance's operation. An analytical balance is used to measure mass to a very high degree of precision and accuracy.

Reagent Bottle


Reagent bottle

It is a container used to hold liquid chemicals. It is usually made up of glass and has a lid which should be replaced immediately after withdrawing chemical from the bottle.


Gas jar

Gas Jar

It is a glass container with a broad base and broad opening. It is used for collecting gas during experiments.

Besides these equipment, there are others like test tube brush, beehive shelf, cork borer, etc. that are used in a chemistry laboratory.


Test tube brush


Beehive shelf


Cork borer

RECORDING AN EXPERIMENT

There is a systematic way of recording an experiment. The experiment is recorded in the notebook in the following manner:

1. Experiment number
2. Aim of the experiment
3. Apparatus or material required
4. Procedure
5. Observation
6. Conclusion or result
7. Precautions

Take a Break!

1. __________ and __________ are used to crush, grind and mix solid substances.
2. A flat-bottom flask is used for heating liquids. (True/False)
3. __________ is used for collecting gas during experiments.
4. A (spatula/dropper) is used to take small quantities of solid chemicals.
5. A glass rod is also known as __________ tube.

SAFETY RULES IN CHEMISTRY LABORATORY

We know that the study of chemistry involves a lot of experimentation. But it is very important to conduct each experiment safely. A few safety signs and symbols which you can see in a chemistry laboratory are shown in Figure.

Safety signs and symbols

Given below is a list of safety rules which should be followed in a chemistry laboratory:

- Before entering the laboratory, wear an apron. Do not wear loose clothes, sandals or contact lens. Tie long hair back and wear safety glasses.
- Carefully follow all the written and verbal instructions.
- Never work alone in the laboratory. Always work under adult supervision.
- Do not touch any equipment, any unknown chemical or any material until instructed. Do not taste or smell any chemical unless specially instructed to do so.
- Arrange the apparatus to be used in the experiment before beginning the experiment.
- Do not eat or drink in the laboratory. Do not use laboratory glassware for eating or drinking purposes.
- Always work in a well-ventilated area and switch-on the exhaust fans.
- While working with volatile substances or poisonous vapours, work in fume hood. Always remember to keep your head out of the fume hood.
- Ask your instructor before disposing of any chemical. Do not throw solid waste in the sink.
- Do not haphazardly mix chemicals. Chemicals should be handled carefully.
- Handle all glassware carefully to avoid breakage.
- Keep your hands away from your body while working with chemicals.
- While heating, make sure that your hair, clothing and hands are at a safe distance from the flame at all the times.
- Check the labels on chemical bottles before using them.
- Wash your hands properly with soap and water after completing experiments.
- Keep your work area clean and tidy. After completing the experiment, do not leave anything on your working table.
- In case of any accidents or injuries, immediately report to your instructor and lab assistants.

SI Units and Conversion Factors الوحدات وعوامل التحويل (1) الجدول

[illegible]h) SI Unit meter (m) المتر

1 kilometer(km) =1000 meter(m)

1 mile = 1.61 kilometer (km)

1 meter(m)=100 centimeter (cm)

الحجم (Volume) SI Unit cubic meter المتر المكعب (m^3)

1 liter (L) = 10^{-3} meter^3 (m^3)

1 liter(L) =1000 milliliter(mL)

1 liter(L)= 1000 centimeter^3 (cm^3)

1 milliliter (mL) =1centimeter^3 (cm^3)

درجة الحرارة (Temperature) SI Unit Kelvin (K)

T Kelvin(K) = t Celsius (°C) +273

°F Fahrenheit = $\frac{9}{5}$ × t Celsius (°C) +32

الكتلة (Mass) SI Unit kilogram (kg)

1 kilogram =1000 grams (1 kg = 1000 g)

1 amu(وكذ) = 1.66×10^{-27} kg

amu (وحدة كتلة ذرية)

الزمن (Time) SI Unit second (s)

1 hour (h) = 60 minutes (min)

1 hour (h)= 3600 seconds (s)

الطاقة (Energy) SI Unit Joule(J)

1 Joule (J) = 1 kg . m^2/s^2 (exact)

1 calorie (cal)= 4.184 Joules (J)

الضغط (Pressure) SI Unit Pascal (Pa)

1 atmosphere (atm) = 101.325 Pascal (Pa)

1 atmosphere(atm) = 760 mm Hg = 760 Torr

1 mmHg =1 Torr

Oher Symbols and abbreviations (المختصرات العلمية)

α alpha particals (دقائق الفا)	h hour (ساعة)	mL milliter (volume) (حجم) مللتر
β beta particals (دقائق بيتا)	J Joule(energy)(وحدة طاقة) جول	mm millimeter (length) (طول) مليمتر
γ gamma rays (اشعة كاما)	K Kelvin (temperature) (حرارة)	mole (amount) (كمية)مول
atomic mass unit (amu) (وحدة كتلة ذرية)	kg kilogram (mass) (كتلة) كيلو غرام	(mp) melting point نقطة انصهار
(aq) aqueous solution (محلول مائي)	kPa kilopascal (pressure) (ضغط) كيلو باسكال	n^0 neutron نيوترون
(atm) atmosphere (pressure)(وحدة ضغط)	L liter (volume) (حجم) لتر	n number of moles عدد المولات
bp boiling point(نقطة الغليان)	(l) liquid (سائل)	n principal quantum number عدد الكم الرئيسي
°C degree Celsius (temperature)(درجة سيليزية)	M molar mass الكتلة المولية	P pressure ضغط
C Speed of light in vacunm (سرعة الضوء)	m meter (length) (طول)متر	p^+ proton بروتون
cm centimeter (lenght)(سنتيمتر وحدة الطول)	m mass كتلة	Pa pascal (pressure) باسكال ضغط
E energy(الطاقة)	V volume حجم	R ideal gas constant ثابت الغاز المثالي
e^- electron(الكترون)	$t_{1/2}$ half- life time زمن عمر النصف	s second ثانية
g gram (mass)(وحدة الكتلة) غرام	T temperature درجة حرارة	(s) solid صلب
(g) gas (غاز)	STP Standard Temperature and Pressure الظروف القياسية	SI international System of Units النظام الدولي للوحدات

ATOMIC NUMBER	NAME	SYMBOL	RELATIVE ATOMIC MASS	GROUP	PERIOD
1	Hydrogen	H	1.00794	1 / IA	1
2	Helium	He	4.002602	18 / VIIIA	1
3	Lithium	Li	6.941	1 / IA	2
4	Beryllium	Be	9.012182	2 / IIA	2
5	Boron	B	10.811	13 / IIIA	2
6	Carbon	C	12.0107	14 / IVA	2
7	Nitrogen	N	14.0067	15 / VA	2
8	Oxygen	O	15.9994	16 / VIA	2
9	Fluorine	F	18.9984032	17 / VIIA	2
10	Neon	Ne	20.1797	18 / VIIIA	2
11	Sodium (Natrium)	Na	22.98976928	1 / IA	3
12	Magnesium	Mg	24.3050	2 / IIA	3
13	Aluminium (Aluminum)	Al	26.9815386	13 / IIIA	3
14	Silicon	Si	28.0855	14 / IVA	3
15	Phosphorus	P	30.973762	15 / VA	3
16	Sulfur	S	32.065	16 / VIA	3
17	Chlorine	Cl	35.453	17 / VIIA	3
18	Argon	Ar	39.948	18 / VIIIA	3
19	Potassium (Kalium)	K	39.0983	1 / IA	4
20	Calcium	Ca	40.078	2 / IIA	4
21	Scandium	Sc	44.955912	3 / IIIB	4
22	Titanium	Ti	47.867	4 / IVB	4
23	Vanadium	V	50.9415	5 / VB	4
24	Chromium	Cr	51.9961	6 / VIB	4
25	Manganese	Mn	54.938045	7 / VIIB	4
26	Iron (Ferrum)	Fe	55.845	8 / VIII	4
27	Cobalt	Co	58.933195	9 / VIII	4
28	Nickel	Ni	58.6934	10 / VIII	4
29	Copper (Cuprum)	Cu	63.546	11 / IB	4
30	Zinc	Zn	65.39	12 / IIB	4
31	Gallium	Ga	69.723	13 / IIIA	4
32	Germanium	Ge	72.64	14 / IVA	4
33	Arsenic	As	74.92160	15 / VA	4
34	Selenium	Se	78.96	16 / VIA	4
35	Bromine	Br	79.904	17 / VIIA	4
36	Krypton	Kr	83.798	18 / VIIIA	4
37	Rubidium	Rb	85.4678	1 / IA	5
38	Strontium	Sr	87.62	2 / IIA	5
39	Yttrium	Y	88.90585	3 / IIIB	5

40	Zirconium	Zr	91.224	4 / IVB	5
41	Niobium	Nb	92.906 38	5 / VB	5
42	Molybdenum	Mo	95.94	6 / VIB	5
43	Technetium	Tc	97.9072*	7 / VIIB	5
44	Ruthenium	Ru	101.07	8 / VIII	5
45	Rhodium	Rh	102.905 50	9 / VIII	5
46	Palladium	Pd	106.42	10 / VIII	5
47	Silver (Argentum)	Ag	107.8682	11 / IB	5
48	Cadmium	Cd	112.411	12 / IIB	5
49	Indium	In	114.818	13 / IIIA	5
50	Tin (Stannum)	Sn	118.710	14 / IVA	5
51	Antimony (Stibium)	Sb	121.760	15 / VA	5
52	Tellurium	Te	127.60	16 / VIA	5
53	Iodine	I	126.904 47	17 / VIIA	5
54	Xenon	Xe	131.293	18 / VIIIA	5
55	Caesium (Cesium)	Cs	132.9054519	1 / IA	6
56	Barium	Ba	137.327	2 / IIA	6
57	Lanthanum	La	138.90547	-	6
58	Cerium	Ce	140.116	-	6
59	Praseodymium	Pr	140.90765	-	6
60	Neodymium	Nd	144.242	-	6
61	Promethium	Pm	144.9127	-	6
62	Samarium	Sm	150.36	-	6
63	Europium	Eu	151.964	-	6
64	Gadolinium	Gd	157.25	-	6
65	Terbium	Tb	158.92535	-	6
66	Dysprosium	Dy	162.500	-	6
67	Holmium	Ho	164.930 32	-	6
68	Erbium	Er	167.259	-	6
69	Thulium	Tm	168.93421	-	6
70	Ytterbium	Yb	173.04	-	6
71	Lutetium	Lu	174.967	3 / IIIB	6
72	Hafnium	Hf	178.49	4 / IVB	6
73	Tantalum	Ta	180.94788	5 / VB	6
74	Tungsten (Wolfram)	W	183.84	6 / VIB	6
75	Rhenium	Re	186.207	7 / VIIB	6
76	Osmium	Os	190.23	8 / VIII	6
77	Iridium	Ir	192.217	9 / VIII	6
78	Platinum	Pt	195.084	10 / VIII	6
79	Gold (Aurum)	Au	196.966569	11 / IB	6
80	Mercury (Hydrargyrum)	Hg	200.59	12 / IIB	6
81	Thallium	Tl	204.3833	13 / IIIA	6

82	Lead (Plumbum)	Pb	207.2	14 / IVA	6
83	Bismuth	Bi	208.98040	15 / VA	6
84	Polonium	Po	208.9824*	16 / VIA	6
85	Astatine	At	209.9871*	17 / VIIA	6
86	Radon	Rn	222.0176*	18 / VIIIA	6
87	Francium	Fr	223.0197*	1 / IA	7
88	Radium	Ra	226.0254*	2 / IIA	7
89	Actinium	Ac	227.0277*	-	7
90	Thorium	Th	232.03806*	-	7
91	Protactinium	Pa	231.03588*	-	7
92	Uranium	U	238.02891	-	7
93	Neptunium	Np	237.0482*	-	7
94	Plutonium	Pu	244.0642*	-	7
95	Americium	Am	243.0614*	-	7
96	Curium	Cm	247.0704*	-	7
97	Berkelium	Bk	247.0703*	-	7
98	Californium	Cf	251.0796*	-	7
99	Einsteinium	Es	252.0830*	-	7
100	Fermium	Fm	257.0951*	-	7
101	Mendelevium	Md	258.0984*	-	7
102	Nobelium	No	259.1010*	-	7
103	Lawrencium	Lr	262.1097*	3 / IIIB	7
104	Rutherfordium	Rf	261.1088*	4 / IVB	7
105	Dubnium	Db	262	5 / VB	7
106	Seaborgium	Sg	266	6 / VIB	7
107	Bohrium	Bh	264	7 / VIIB	7
108	Hassium	Hs	277	8 / VIII	7
109	Meitnerium	Mt	268	9 / VIII	7
110	Darmstadtium	Ds	271	10 / VIII	7
111	Roentgenium	Rg	272	11 / IB	7
112	Ununbium	Uub	285	12 / IIB	7
113	Ununtrium	Uut	284	13 / IIIA	7
114	Ununquadium	Uuq	289	14 / IVA	7
115	Ununpentium	Uup	288	15 / VA	7
116	Ununhexium	Uuh	292	16 / VIA	7
117	Ununseptium	Uus	-	17 / VIIA	7
118	Ununoctium	Uuo	294	18 / VIIIA	7

*Relative atomic mass of the isotope of the element with the longest known half-life.

Periodic Table of the Elements

Atomic Number	6
Symbol	C
Name	Carbon
Average Atomic Mass	12.0107

Hydrogen
Semiconductors (also known as metalloids)

Metals
Alkali metals
Alkaline-earth metals
Transition metals
Other metals

Nonmetals
Halogens
Noble gases
Other nonmetals

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
1	1 H Hydrogen 1.007 94																	2 He Helium 4.002 60
2	3 Li Lithium 6.941	4 Be Beryllium 9.012 182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.998 4032	10 Ne Neon 20.1797
3	11 Na Sodium 22.989 769 28	12 Mg Magnesium 24.3050											13 Al Aluminum 26.981 5386	14 Si Silicon 28.0855	15 P Phosphorus 30.973 762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955 912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938 045	26 Fe Iron 55.845	27 Co Cobalt 58.933 195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.409	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.921 60	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.905 85	40 Zr Zirconium 91.224	41 Nb Niobium 92.906 38	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.905 50	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.904 47	54 Xe Xenon 131.293
6	55 Cs Cesium 132.905 4519	56 Ba Barium 137.327	57 La Lanthanum 138.905 47	72 Hf Hafnium 178.49	73 Ta Tantalum 180.947 88	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966 569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.980 40	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub* Ununbium (285)		114 Uuq* Ununquadium (289)		116 Uuh* Ununhexium (292)		

* The systematic names and symbols for elements greater than 111 will be used until the approval of trivial names by the IUPAC.

The discoveries of elements with atomic numbers 112, 114, and 116 have been reported but not fully confirmed.

58 Ce Cerium 140.116	59 Pr Praseodymium 140.907 65	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925 35	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930 32	68 Er Erbium 167.259	69 Tm Thulium 168.934 21	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
90 Th Thorium 232.038 06	91 Pa Protactinium 231.035 88	92 U Uranium 238.028 91	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

The atomic masses listed in this table reflect the precision of current measurements. (Each value listed in parentheses is the mass number of that radioactive element's most stable or most common isotope.)